ORANGE COUNTY WATER DISTRICT

ORANGE COUNTY'S GROUNDWATER AUTHORITY

February 14, 2011

Robert Holub
Division Chief
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, CA 92501

Subject: Groundwater Remediation at Northrop Y-12 Site

Dear Mr. Holub:

Orange County Water District (OCWD) staff has prepared this letter to express our concerns with the current status of the Northrop Y-12 site remediation and the apparent direction toward which it is heading. For more than a year, Northrop's efforts have been focused on planning and implementing a recirculation well pilot test. As we have discussed, the recirculation well pilot test was unsuccessful due to substantial bromate formation. In addition, OCWD staff has explained its position that the recirculation well approach propounded by Northrop results in the widening of volatile organic compound (VOC) plumes flowing onto the Y-12 site in the lower part of the Shallow Aquifer. To further evaluate this issue, OCWD commissioned a groundwater modeling evaluation by our consultant, GeoTrans. Attached are the evaluation results that support our position that the recirculation well widens existing VOC plumes by injecting treated water into the contaminated lower portion of the Shallow Aquifer.

We understand that Northrop plans on evaluating and pilot testing the use of ultra-violet light (UV) as an alternative to ozone in the treatment cell within the recirculation well. OCWD staff researched the use of ultra-violet light in recirculation wells, including inquiring with the U.S. Environmental Protection Agency (EPA) Office of Research and Development in Cincinnati, Ohio, and the U.S. EPA Robert S. Kerr Research Center in Ada, Oklahoma. Our research failed to find a single application, successful or otherwise, of ultra-violet light within a recirculation well. We consider such an application as only theoretical and not demonstrated to be practical or cost effective. Furthermore, use of ultra-violet light would not mitigate the aforementioned problems associated with the spreading of existing contamination that would be inherent with operating one or more recirculation wells in the manner suggested by Northrop. The Northrop Y-12 site continues to be a significant source of groundwater contamination that is migrating off site unabated. We respectfully request that the

RWQCB direct Northrop to abandon the recirculation well approach in favor of a proven groundwater remedy, such as pump and treat, that will effectively extract and prevent the further spread of contamination from the Y-12 site.

We appreciate the Regional Board staff's continued vigilance in overseeing this important remedial effort. If you have any questions regarding this letter or the attached modeling evaluation, please do not hesitate to call Roy Herndon (714-378-3260) or Dave Mark (714-378-3337).

Sincerely,
ORANGE COUNTY WATER DISTRICT

Roy Herndon
Roy Herndon, P.G., C.HG.
Chief Hydrogeologist

Dave Mark
Dave Mark, P.G., C.HG.
NBGPP Project Manager

Attachment

Copies: Ann Sturdivant, SARWQCB

GeoTrans, Inc.
A TETRA TECH COMPANY
2 Paragon Way
Freehold, NJ 07728
www.geotransinc.com (732) 409-0344 FAX (732) 409-3020

November 15, 2010

Mr. Dave Mark
Orange County Water District
18700 Ward Street
Fountain Valley, CA 92708

Re: Report - Model Evaluation of Recirculation Well
GeoTrans Project 117-1068002

Dear Mr. Mark:

At your request, GeoTrans has prepared this report with results from modeling conducted for the above-referenced project.

OBSERVATIONS REGARDING MODELING DISCUSSION IN ATTACHMENT H OF ORION REPORT

GeoTrans was provided with the following document: *"Report for Pilot Test of Groundwater Circulation Well with In-Casing Oxidation Former Northrop Grumman Y-12 Facility, 301 E. Orangethorpe Avenue, Anaheim, California"*, by Orion Environmental, Inc. (April 23, 2010). Attachment H of that report described modeling performed by GeoKinetics regarding a recirculation well. Pertinent pages from that document are included in Attachment A of this report. Key observations regarding the information provided in Attachment H of the Orion Report include the following:

- Figure 1 in Attachment H of the Orion Report is a well construction diagram of recirculation well CW-1. This figure indicates the following:
  - Top screen interval (for extraction) is from 110 ft bgs to 148 ft bgs (i.e., screen length is 38 ft)
  - Blank casing separating the screens is from 148 ft bgs to 175 ft bgs (i.e., blank casing length is 27 ft)
  - Bottom screen interval (for injection) is from 175 ft bgs to 193 ft bgs (i.e., screen length is 18 ft)
- The modeling section in Attachment H of the Orion Report states that the modeling GeoKinetics performed used a regional model by OCWD as a basis for a more local model using a telescopic mesh refinement (TMR) approach. A specific reference for the OCWD regional model (i.e., run number, date, etc.) is not provided. It further states that aquifer parameters and lithology data were revised versus the regional OCWD model based on

available lithology data near the Y-12 site and measurements made during the pilot test at CW-1. The specific lithology in the TMR model near CW-1 is not provided. The following information is provided regarding parameter values for the TMR model in the shallow aquifer:

  - Kh = 450 ft/d
  - Ky = 90 ft/d
  - Vertical anisotropy = 5:1
  - Effective porosity = 25%

- The horizontal extent and horizontal grid spacing for the TMR model by GeoKinetics are not provided

- The Orion report does not say for what specific time period in the OCWD regional model the boundary conditions in the TMR model are based on, and it also does not state the nature of the TMR model boundaries (specified head or specified flux).

- The Orion report states that Layer 1 in the OCWD regional model, which represents the Shallow Aquifer, is divided into three layers of equal thickness and identical parameter values in the TMR model. However, the report does not state what these equal thickness values are, and does not state how the thickness of layer 1 (which is unconfined) was determined (i.e., top minus bottom, or initial head minus bottom). Furthermore, the Orion report does not state why layers of equal thickness were used since the screen intervals and blank interval for CW-1 are not equal (38 ft for top extraction screen, 27 ft for blank casing, and 18 ft for bottom injection screen).

- Note that effective porosity does not impact MODFLOW results or particle tracks. It only impacts the velocity of the particles.

- Figure 14 in Attachment H of the Orion Report only shows two-dimensional particle tracks. The Orion report does not indicate if the particles were tracked forwards or backwards (i.e., the starting locations are not identified). Additionally, the relative depth within each layer where particles were started was not identified. The particle tracking results on Figure 14 in Attachment H of the Orion report do not provide any insight regarding vertical recirculation from layer 3 to layer 1, and the report provides no further insight into the degree to which water injected to model layer 3 is recirculated to model layer 1. It also does not provide insight regarding the degree to which impacted water in layer 3 (the deeper portion of the shallow aquifer) might be displaced by the injected water.

MODELING OBJECTIVES

The following is from the scope of work provided to GeoTrans by OCWD: "Northrop's consultants have conducted modeling of the recirculation well and have quantified upgradient and downgradient capture zones. However, they have not quantified (or at least shared with the District) the vertical flow, and specifically how much, if any, recirculation occurs. The degree of recirculation is very important since, at the Northrop Y-12 site, the VOC concentrations in lower part of the Shallow Aquifer are more than double the concentrations in the upper part of the aquifer. Without significant recirculation, the water injected into the lower part of the Shallow Aquifer will displace the contaminated groundwater, causing the plume to expand laterally and in a downgradient direction. This could exacerbate the problem and make it more difficult and costly for the District to contain the plume further downgradient. The objective of the modeling is to evaluate the degree of recirculation and possible displacement of the plume in the lower part of the Shallow Aquifer."

The scope of the modeling performed herein includes the following:

- Using the same aquifer parameters used by Northrop in their modeling analysis, which includes a ratio of horizontal to vertical hydraulic conductivity of 5:1, conduct a local-scale three-dimensional flow analysis of the recirculation well that shows in cross-section the modeled flow path of water injected into the lower part of the Shallow Aquifer.

- Also, use the same model configuration, but increase the ratio of horizontal to vertical hydraulic conductivity to 10:1.

- Compare the aquifer parameters used by Northrop's consultant with the values used in the calibrated refined model GeoTrans prepared for the District to support the NBGPP.

- Quantify the percent of the injected water that is captured by the upper screened interval and the percent that flows downgradient without being recirculated. Quantify the volume of water in the lower part of the Shallow Aquifer that is displaced by water that was not recirculated.

- Conduct a sensitivity analysis of variations in horizontal and vertical hydraulic conductivity between the upper and lower screened intervals.

- Illustrate the extent to which groundwater in the lower part of the shallow aquifer is displaced as a result of operation of the recirculation well.

- Illustrate the extent to which upgradient water in the lower part of the Shallow Aquifer is displaced as a result of operation of the recirculation well.

- Illustrate the extent to which water injected by the recirculation well remains in the lower part of the Shallow Aquifer.

MODELING APPROACH AND MODEL CONSTRUCTION

The approach for Task 1 included the construction of a simplified three dimensional model that was reasonably similar to the GeoKinetics model. It was not possible to exactly duplicate the GeoKinetics model because key details regarding the grid extent, grid spacing, layer elevations, and boundary conditions were not provided. The parameter values reported in the Orion report were utilized, and an attempt was made to reproduce the simulated water levels illustrated on Figure 14 in Attachment H of the Orion Report. Furthermore, predicted horizontal particle tracks were compared to the particle tracks presented on Figure 14 in Attachment H of the Orion Report.

Modeling Codes

Flow modeling was performed using MODFLOW-2000, and particle tracking was performed with MODPATH version 3, as implemented in Groundwater Vistas version 5.33 Build 21.

Horizontal Model Extent and Horizontal Grid Spacing

The GeoTrans local model grid is rotated from north 4 degrees clockwise, and the lower left hand corner of the model grid is (6050736.8, 2256335.3) in NAD 1983 State Plane California VI FIPS 0406 (ft). The rotation approximately aligns the local model columns with the water level contours on Figure 14 in Attachment H of the Orion Report, which simplifies the specification of boundary conditions. The GeoTrans local model has 187 rows and 187 columns. Recirculation well CW-1 is in the middle of the model grid, and the model grid spacing is symmetrical relative to that well in all four directions. The model length is 10,001 ft in both the X and Y directions. The maximum grid spacing is 100 ft, and the minimum grid spacing near well CW-1 is 1 ft. A portion of the grid near CW-1 is presented in Figure 1 to illustrate the range in grid spacing. The grid extent was selected so that boundaries are sufficiently far from well CW-1 such that boundary assignment does not affect simulation of drawdown and/or capture.

Vertical Layering

Layers in this simplified local model are flat, and layer elevations and thicknesses are summarized below:

Layer	Top Elev (Ft MSL)	Bottom Elev (ft MSL)	Thickness (ft)	Comment
1	70	20	*	Extraction Interval – Upper Portion of Shallow Aquifer
2	20	-7	27	Blank Casing – Middle Portion of Shallow Aquifer
3	-7	-25	18	Injection Interval – Lower Portion of Shallow Aquifer
4	-25	-50	25	Aquitard between Shallow and Principal Aquifer
5	-50	-1500	1450	Principal Aquifer

**varies across model domain based on simulated water levels, ~34 ft near CW-1*

The primary interest for this modeling is layers 1 to 3. Layers 4 and 5 are included to allow for the possibility of vertical flow from the Shallow Aquifer to the Principal Aquifer, and vice versa. Layer 1 is simulated as unconfined (Layer Type = 1), and the other layers are assigned as convertible (Layer Type = 3), but given the head distribution in this model, the lower layers act as confined units.

Aquifer Parameters

Hydraulic conductivity is assigned as follows:

- Layers 1 to 3: Kh = 450 ft/d, Kv = 90 ft/d (consistent with GeoKinetics model)
- Layer 4: Kh = Kv = 0.001 ft/d
- Layer 5: Kh = 100 ft/d, Kv = 20 ft/d

Note that in the Groundwater Model Refinement that GeoTrans performed for OCWD (report dated January 21, 2010) the hydraulic conductivity in the shallow aquifer (which corresponds to layers 1 to 3 in this local model) in the vicinity of CW-1 is 275 ft/d, with a vertical anisotropy ratio of 5:1. The values assigned for model layers 4 and 5 are generally consistent with values that GeoTrans believes are specified in the OCWD model that GeoKinetics may have used as a basis for their TMR model.

Steady state modeling is performed so no storage coefficient is assigned. Porosity (for particle tracking velocity) is assigned as 0.25 (consistent with GeoKinetics model).

Boundary Conditions

Specified heads are assigned on the western and eastern edges of the model, with the same value assigned in all five layers. A head of 65.38 ft MSL was assigned on the western (upgradient) edge of the model, and a head of 41.1 ft MSL was assigned on the eastern (downgradient) edge of the model. These values were selected to generally duplicate the water levels presented on Figure 14 in Attachment H of the Orion report. Well CW-1 was represented with an extraction well in model layer 1 (- 11,551 ft3/d), and an injection well in model layer 3 (11,551 ft3/d). These rates correspond to 60 gpm extracted and injected. No net recharge is assigned, and there are no inactive cells.

Numerical Solution

The PCG2 solution package in MODFLOW-2000 was utilized to iteratively solve the finite difference equations for flow. A convergence criterion of 0.0001 ft and a residual criterion of 1 ft^3/d were utilized, and the resulting mass balance error reported by MODFLOW was sufficiently small (the achieved mass balance error was generally 0.00%).

SUMMARY OF RESULTS – BASE CASE

Figure 2 presents a comparison of simulated water levels and particle tracks in model layer 1 for the GeoTrans local model versus the GeoKinetics model. For the GeoTrans model, a line of particles was released at the vertical midpoint of layer 1, at the locations illustrated on Figure 2, and tracked forward. The water levels match quite closely between the GeoTrans model (red) and the GeoKinetics model (blue), as do the particle tracks. This confirms that the GeoTrans model results are generally consistent with the GeoKinetics model. Figure 3 represents a similar comparison for model layer 3. In this case, the GeoTrans particles were initiated in a circle around the injection well, radius of 1 foot, starting 25% up from the bottom of the cell, and were tracked forward. The comparison is reasonable (though the orientation of the flow direction varies slightly). The GeoTrans capture results for layer 3 will vary depending on the depth that the particles start (not illustrated). The deeper the particles start, the wider the capture zone. Since GeoKinetics did not state how they performed the particle tracking, it is not possible to make a direct comparison, but the results again confirm that the GeoTrans local model results are generally consistent with the GeoKinetics model.

The GeoTrans model was then utilized to assess the degree to which water injected in the bottom well screen (layer 3) is recirculated back to the top well screen (model layer 1), given the parameters in the GeoKinetics model. To assess this, 160 particles were released in model layer 3 in a cylindrical pattern around the injection well screen. The particles were released at a radial distance of 1 foot from well CW-1, and tracked forward. The cylindrical pattern includes 16 particles released around the well at 10 different depth intervals (5% of layer 3's thickness from the bottom, 15% from the bottom, 25% from the bottom, etc.), resulting in 160 particles. The percentage of those particles tracked to the upper well screen represents an approximation of the percentage of water that recirculates between well screens. The results indicate that 18 of the 160 particles (11%) are captured by the upper well screen and that 142 of the 160 particles (89%) are not captured and displace other water. The origin of the 18 particles captured by the extraction well is illustrated on Figure 4. All of the recirculation occurs from the upgradient side of the injection well screen, and the depth to which the recirculation occurs in layer 3 diminishes away from locations that are directly upgradient of the recirculation well.

Figure 5 a "map view" that illustrates the complexity of the simulated flow path for a specific particle that originates near the injection well screen in model layer 3 (75% of the way up from the bottom of layer 3), and ultimately is captured by the extraction well screen in model layer 1. The color of the flow path changes when the particle enters a new model layer. The water injected at this point flows to the northeast in model layer 3, to the northwest in model layer 2, and ultimately to the southeast back to the extraction screen in model layer 1.

The three-dimensional pattern in which particles that originate in the deep part of the Shallow Aquifer (layer 3) are captured by the extraction well in layer 1 is further illustrated in Figures 6 to 8. To make these figures, particles were released in every cell in layer 3 (within a specific window), at a specific starting depth. The particles that were captured by the extraction well in layer 1 were then highlighted. Figure 6 illustrates the capture of particles that start 95% up from the bottom of layer 3, and compares this to the capture of particles from Layer 1 illustrated on Figure 14 in Attachment H of the Orion Report. As expected, the capture zone from the top portion of model layer 3 is smaller than the capture zone from model layer 1. Also, all of the particles captured from layer 3 are from the upgradient side of the injection well. Figure 7 illustrates the capture of particles that start 50% up from the bottom of layer 3, and comparison to Figure 5 illustrates that the capture zone narrows with depth. Figure 8 illustrates the capture of particles that start 5% up from the bottom of layer 3, and it indicates that almost no capture occurs from this depth. These figures illustrate that only water from upgradient of the recirculation well in layer 3 is captured by the extraction well in model layer 1, and that zone gets narrower with depth in model layer 3.

SENSITIVITY ANALYSIS REGARDING PERCENTAGE OF RECIRCULATED WATER

First, a sensitivity analysis was conducted to determine the impact of vertical anisotropy in model layer 1 to 3 on the percentage of water recirculated from the bottom well screen to the top well screen. This was performed using the same method as with the base case (16 particles released in layer 3 at 10 different depth intervals, at a radius of 1 foot from the recirculation well). The results are summarized below:

Vertical Anisotropy Layers 1 to 3	% Injected Water Recirculated	% Injected Water That Displaces Other Water
10:1	6%	94%
5:1	11%	89%
1:1	36%	64%

These results are consistent with expectations that the degree of recirculation increases as vertical anisotropy decreases. For the case with higher vertical anisotropy, capture zone width in layer 1 will be wider, and capture zone width in layer 3 (for a given depth) will be narrower. Figure 9 is similar to Figure 4 (i.e., illustrates which of the 160 particles are recirculated back to the upper well screen), but for a case with 10:1 vertical anisotropy rather than 5:1. With 10:1 vertical anisotropy, only the particles that start directly upgradient of the injection well are recirculated to the upper well screen.

Next, a sensitivity analysis was performed to determine the impact of variations in horizontal hydraulic conductivity in layers 1 to 3 on the percentage of water recirculated from the bottom well screen to the top well screen. This was performed using the same method as with the base case (16 particles released in layer 3 at 10 different depth intervals, at a radius of 1 foot from the recirculation well). In each case, the vertical anisotropy was assigned as 5:1. Hydraulic conductivity values were varied by a factor of 2. The results are summarized below:

Scenario for Kh (ft/d)	% Injected Water Recirculated	% Injected Water That Displaces Other Water
K1 = 450 K2 = 450 K3 = 450	11%	89%
K1 = 225 K2 = 450 K3 = 450	16%	84%
K1 = 450 K2 = 450 K3 = 225	16%	84%
K1 = 225 K2 = 225 K3 = 225	32%	68%
K1 = 900 K2 = 900 K3 = 900	4%	96%

These sensitivity results indicate that differences in hydraulic conductivity values assigned in model layers 1 to 3 do have some impact on the degree of recirculation. The most significant changes occurred when the overall hydraulic conductivity of all three layers was modified; the lower the horizontal hydraulic conductivity, the greater the degree of recirculation. However, in all of the cases the vast majority of injected water through the bottom well screen is not recirculated, such that the majority of injected water displaces other water.

DEGREE OF DISPLACEMENT DUE TO THE RECIRCULATION WELL

Further analysis was performed to illustrate the degree to which the injection of water to the deeper well screen displaces groundwater. The easiest way to illustrate this is to evaluate the extent to which groundwater flowing towards the injection well screen from upgradient is diverted by the injected water. This is illustrated for particles originating upgradient of the recirculation well, starting at different depth intervals in layer 3:

Figure 10a – Particles originating 10% up from the bottom of layer 3
Figure 10b – Particles originating 30% up from the bottom of layer 3
Figure 10c – Particles originating 50% up from the bottom of layer 3
Figure 10d – Particles originating 70% up from the bottom of layer 3
Figure 10e – Particles originating 90% up from the bottom of layer 3

In each case the initial line of particles upgradient of the recirculation well is 200 ft wide, and in the absence of recirculation the particle width would remain 200 ft wide (based on groundwater flow only). As illustrated on Figure 10a, for particles starting in the deeper portion of model layer 3, the displacement caused by the reinjection of water causes the particles to diverge, resulting in northern and southern portions of particles. This widens the zone of impacted area (represented by the initial particle locations) from 200 ft to 260 ft, with a portion of “clean” injected water that is causing the displacement in the middle. Most of the water originating in the deeper part of layer 3 stays in layer

3, though a few of the particles flow up into model layer 2. This flow pattern suggests that the recirculation well can potentially complicate the capture and treatment of impacted groundwater downgradient of the recirculation well, by making the plume wider (and more complicated geometrically). As noted at the top of Figure 10a, this pattern is enhanced as the vertical anisotropy increases. For a 10:1 vertical anisotropy, the zone of impacts (represented by the initial particle locations) increases from 200 ft to 300 ft, rather than to 260 ft for a 5:1 anisotropy ratio.

Figures 10b to 10e illustrate that much of the water originating upgradient of the recirculation well in shallower portions of model layer 3 will flow up to model layer 2, and some will flow up to model layer 1 as well. Some of the water that flows to model layer 1 will be captured by the extraction screen of the recirculation well, and the rest continues to flow to the west and is not captured. There is still some divergence of the flow path around the recirculation well even for particles starting in the upper portion of layer 3, though the added width of the impacted area (represented by the initial particle locations) is reduced from 260 ft in the deeper part of layer 3 to 227 ft in the upper part of layer 3 (versus 200 ft without the recirculation well).

EXTENT TO WHICH INJECTED WATER STAYS IN DEEP PART OF SHALLOW AQUIFER

The extent to which water injected by the recirculation well remains in the lower part of the Shallow Aquifer (i.e., model layer 3) is illustrated in Figures 11a to 11e:

Figure 11a – Particles originating 10% up from the bottom of layer 3
Figure 11b – Particles originating 30% up from the bottom of layer 3
Figure 11c – Particles originating 50% up from the bottom of layer 3
Figure 11d – Particles originating 70% up from the bottom of layer 3
Figure 11e – Particles originating 90% up from the bottom of layer 3

In each case, 16 particles were released in a one foot radius around the injection well screen. Figure 11a illustrates that water injected near the bottom of layer 3 generally stays in layer 3. For water injected shallower in model layer 3, more of the injected water flows up into model layer 2, and some ends up in model layer 1. However, as discussed earlier, only a small portion of the injected water is subsequently captured by the extraction well screen in model layer 1.

Please contact me at 732-409-0344 if you have any questions or concerns.

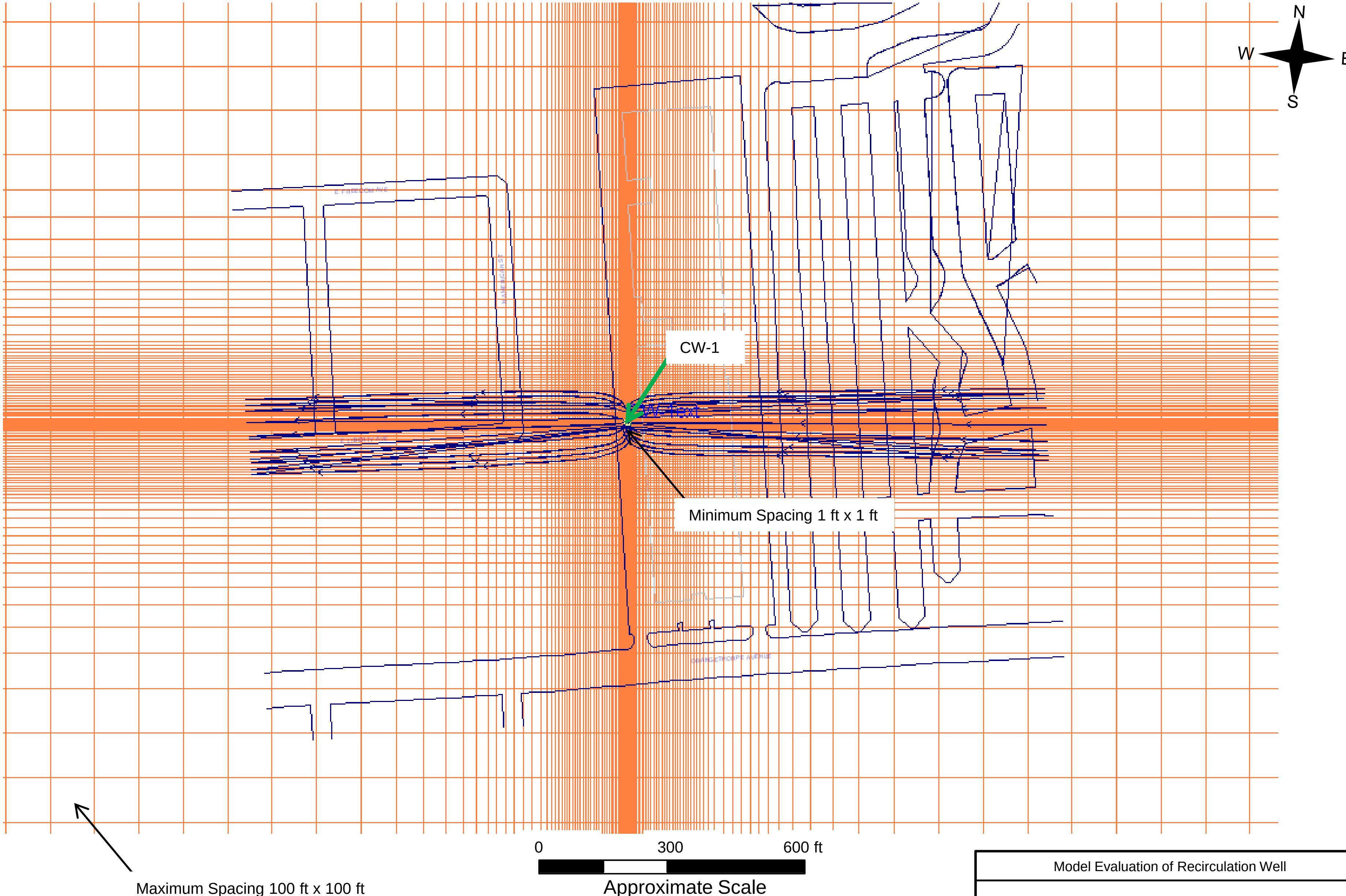
Sincerely,

Robert M. Greenwald
Principal Hydrogeologist

Attachments:

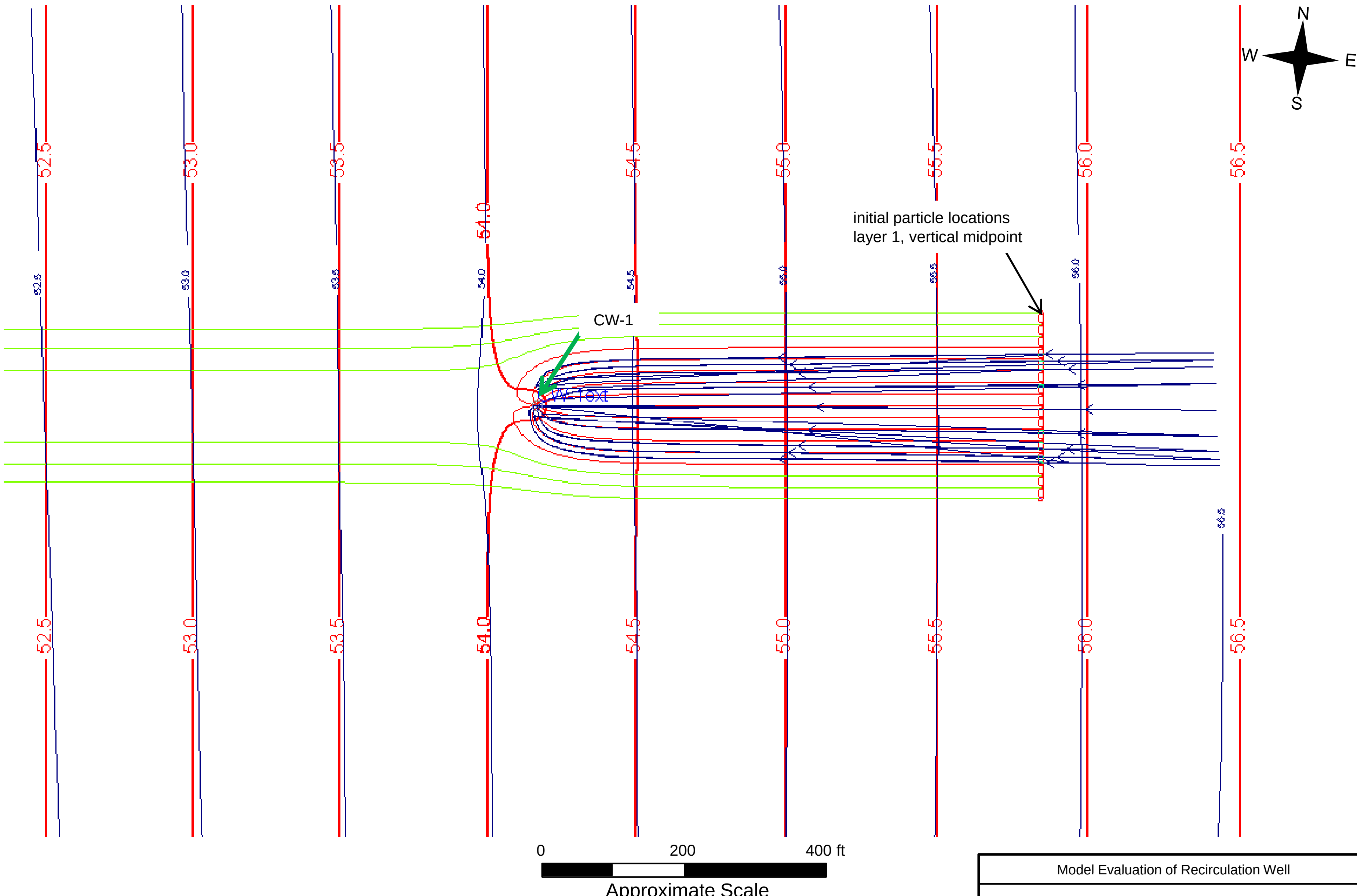
Attachment A: Selected Pages from “Attachment H” of Orion Environmental Report (4/23/10)

Figures



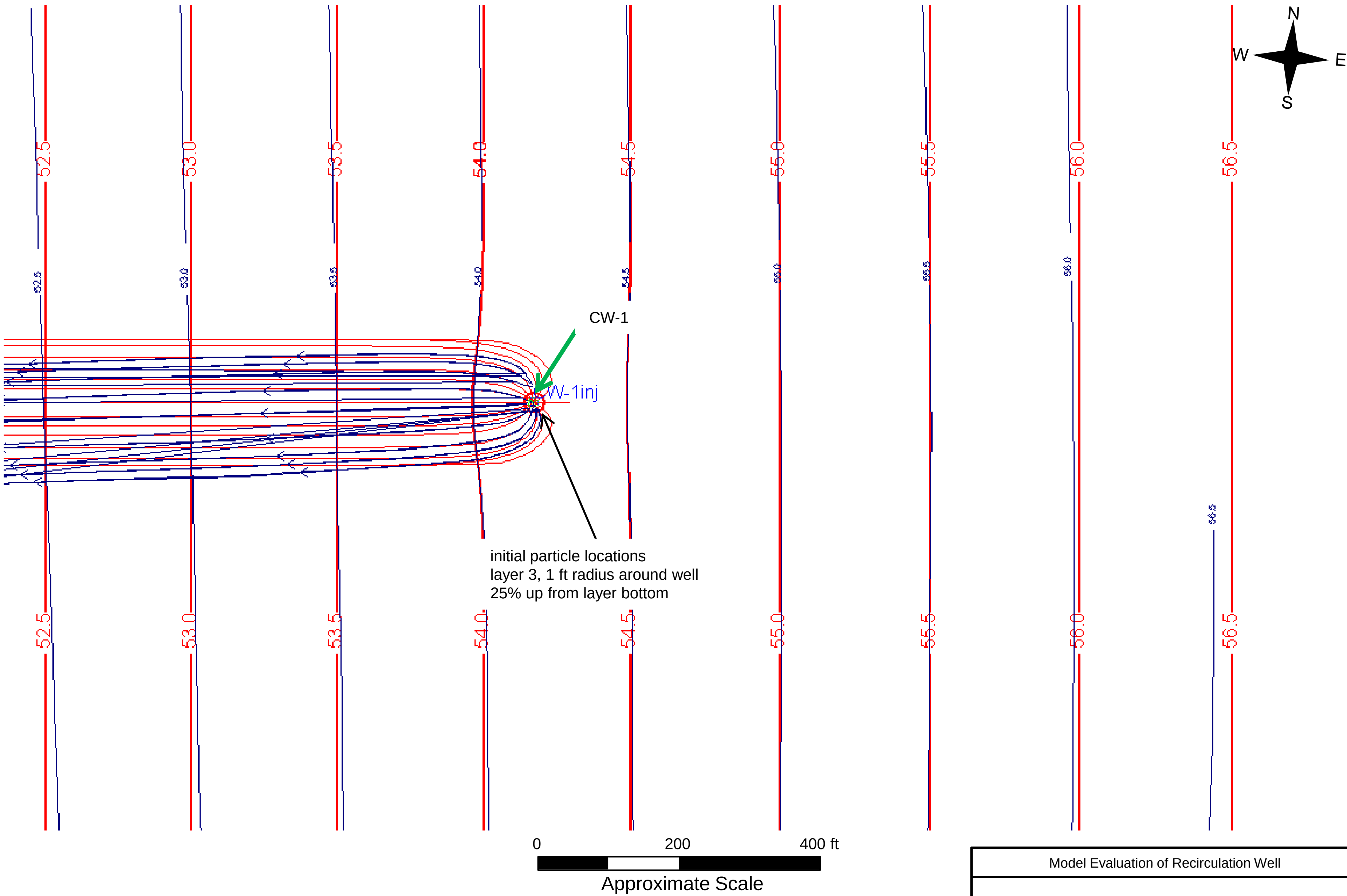
Note: Basemap features (including particle tracks) were digitized from Figure 14 in Attachment H of the Orion Report. Model Grid is for model by GeoTrans.

Model Evaluation of Recirculation Well		
Portion of GeoTrans Horizontal Grid Illustrating Range of Spacing		
GeoTrans, Inc.	By: RMG Modified: 10/11/10	**Figure** 1



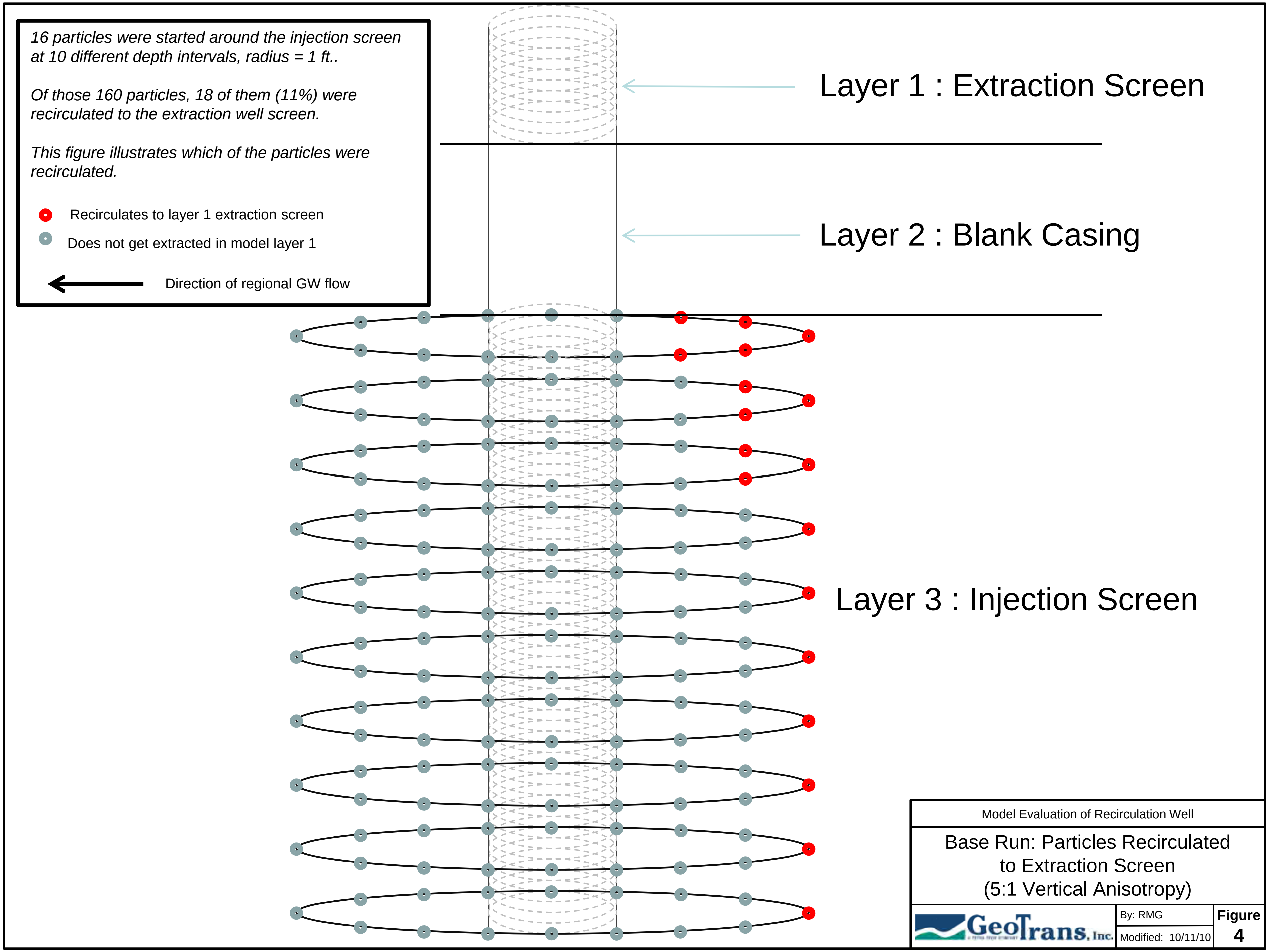
Blue = GeoKinetics Results from Figure 14 in Attachment H of the Orion Report.
Red = GeoTrans Model Results
Green = Not Captured in GeoTrans Model

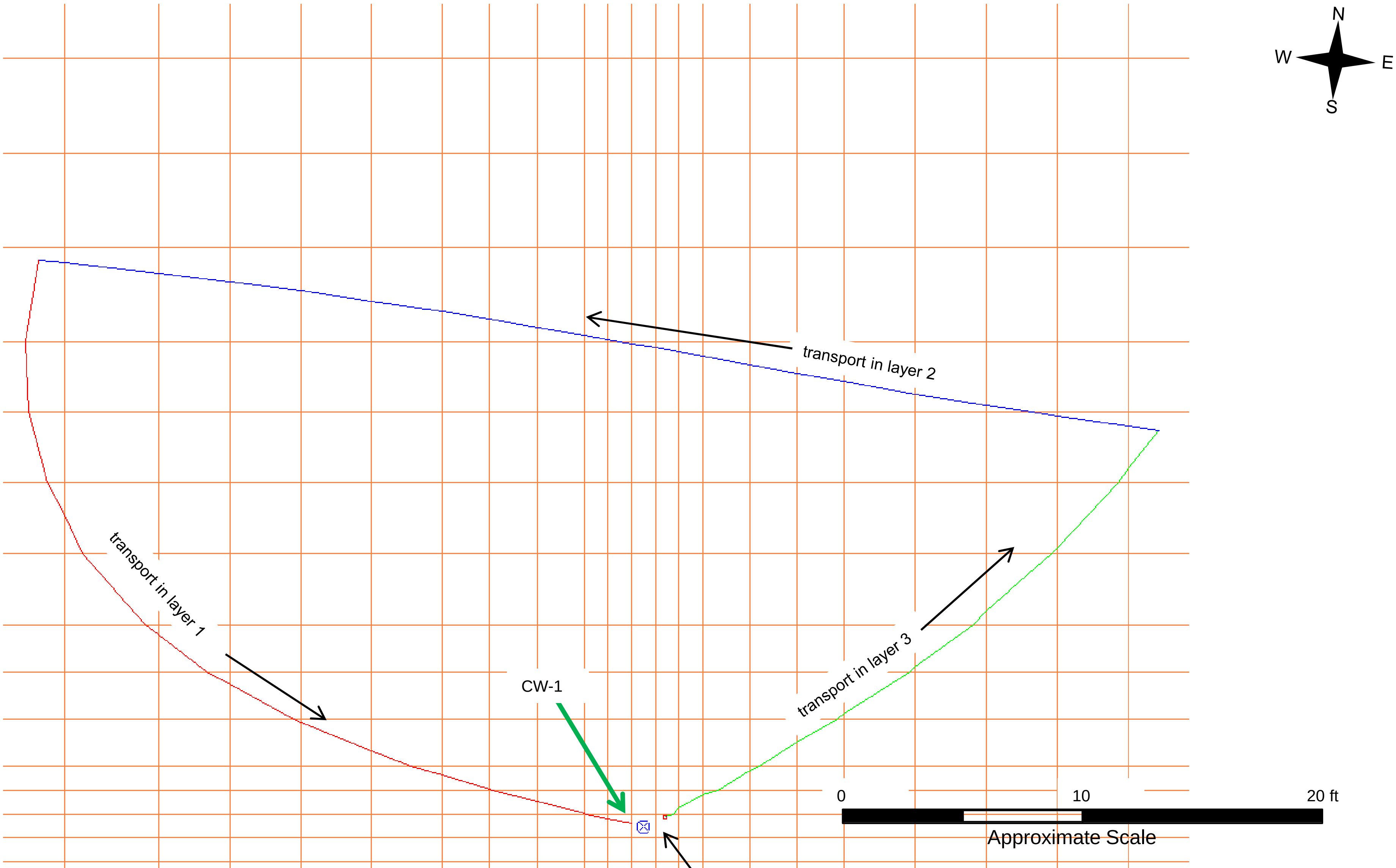
Model Evaluation of Recirculation Well		
Comparison of Heads and Particle Tracks, Model Layer 1		
GeoTrans, Inc.	By: RMG Modified: 10/11/10	**Figure 2**



Blue = GeoKinetics Results from Figure 14 in Attachment H of the Orion Report.
Red = GeoTrans Model Results

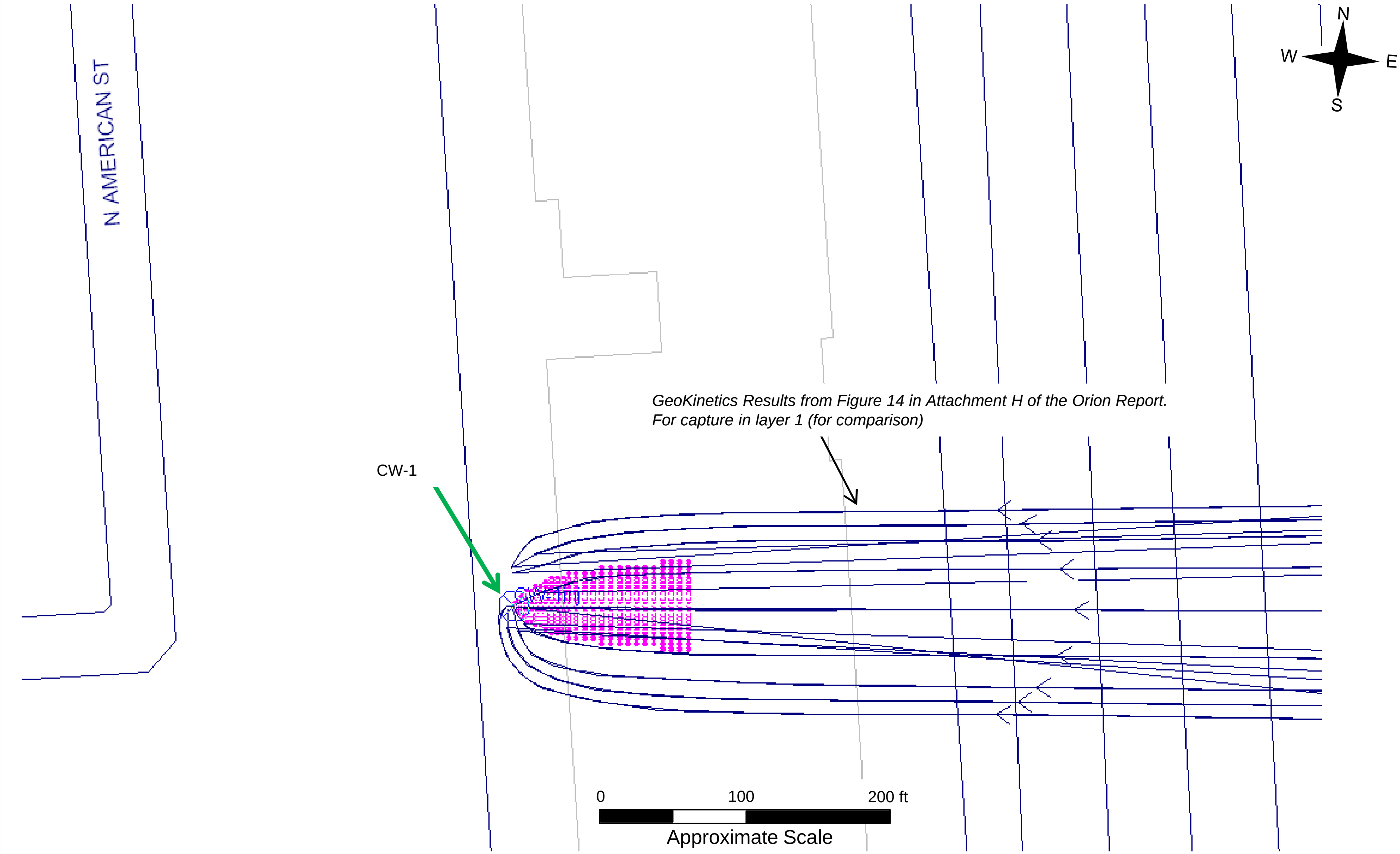
Model Evaluation of Recirculation Well		
Comparison of Heads and Particle Tracks, Model Layer 3		
GeoTrans, Inc.	By: RMG Modified: 10/11/10	Figure 3


16 particles were started around the injection screen at 10 different depth intervals, radius = 1 ft..
Of those 160 particles, 18 of them (11%) were recirculated to the extraction well screen.
This figure illustrates which of the particles were recirculated.
Recirculates to layer 1 extraction screen
Does not get extracted in model layer 1
Direction of regional GW flow
Layer 1 : Extraction Screen
Layer 2 : Blank Casing
Layer 3 : Injection Screen
Model Evaluation of Recirculation Well
Base Run: Particles Recirculated to Extraction Screen (5:1 Vertical Anisotropy)
GeoTrans, Inc.
By: RMG
Modified: 10/11/10
Figure 4



This is a “map view” that illustrates the complexity of the simulated flow path for a specific particle that originates near the injection well screen in model layer 3 (75% of the way up from the bottom of layer 3), and ultimately is captured by the extraction well screen in model layer 1. The color of the flow path changes when the particle enters a new model layer.

Model Evaluation of Recirculation Well	
Illustration of a Particle Trajectory for one Recirculated Particle	
GeoTrans, Inc.	By: RMG Modified: 10/11/10
Figure 5	



Blue = GeoKinetics Results from Figure 14 in Attachment H of the Orion Report

Magenta = GeoTrans Model Results, Capture for Particles Originating in Model Layer 3, Starting 95% up from the bottom of Layer 3 (capture zone continues to the east of the area illustrated)

Model Evaluation of Recirculation Well

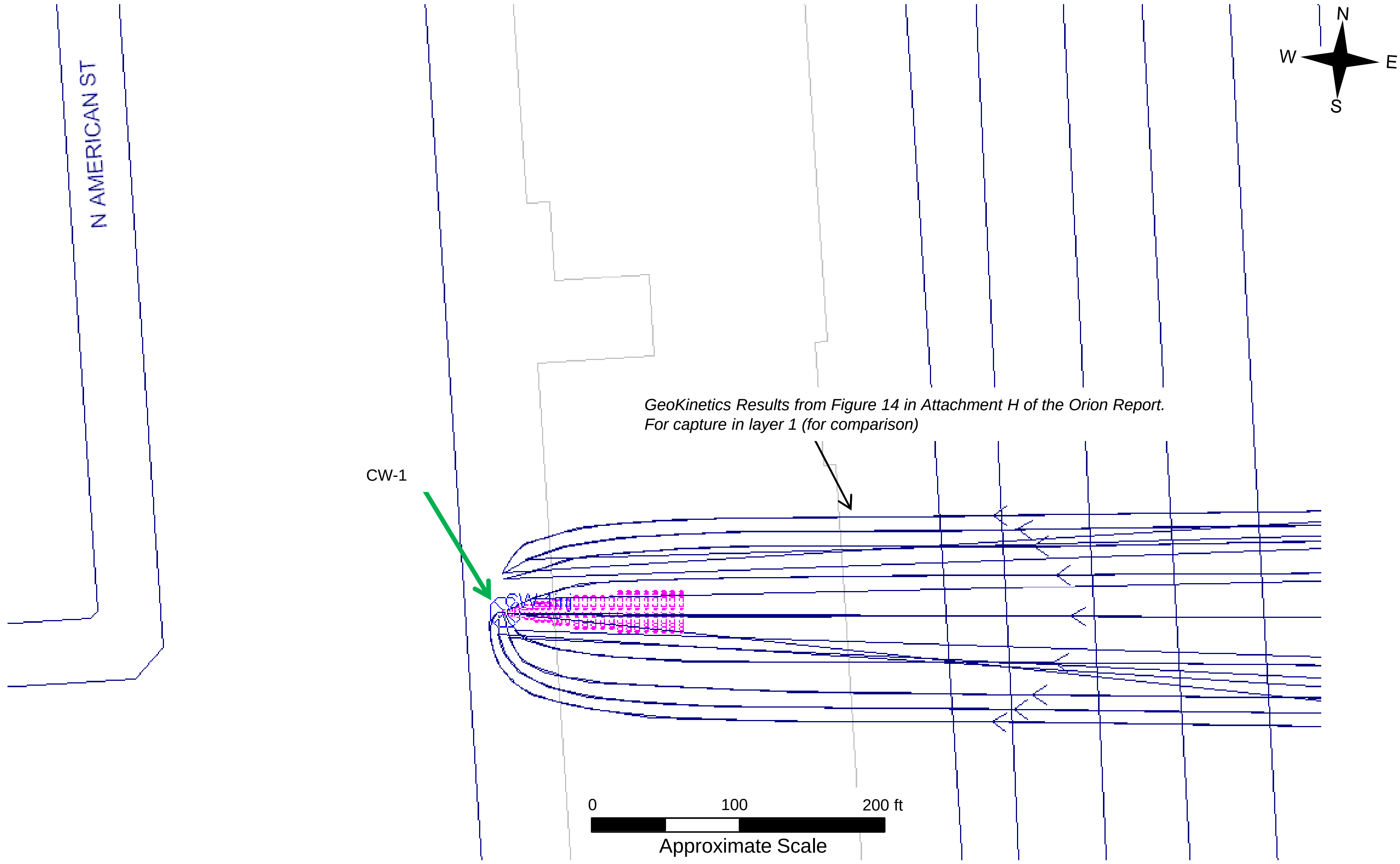
Recirculation Zone for Particles In Layer 3 Starting 95% from Bottom

GeoTrans, Inc.

By: RMG

Modified: 10/11/10

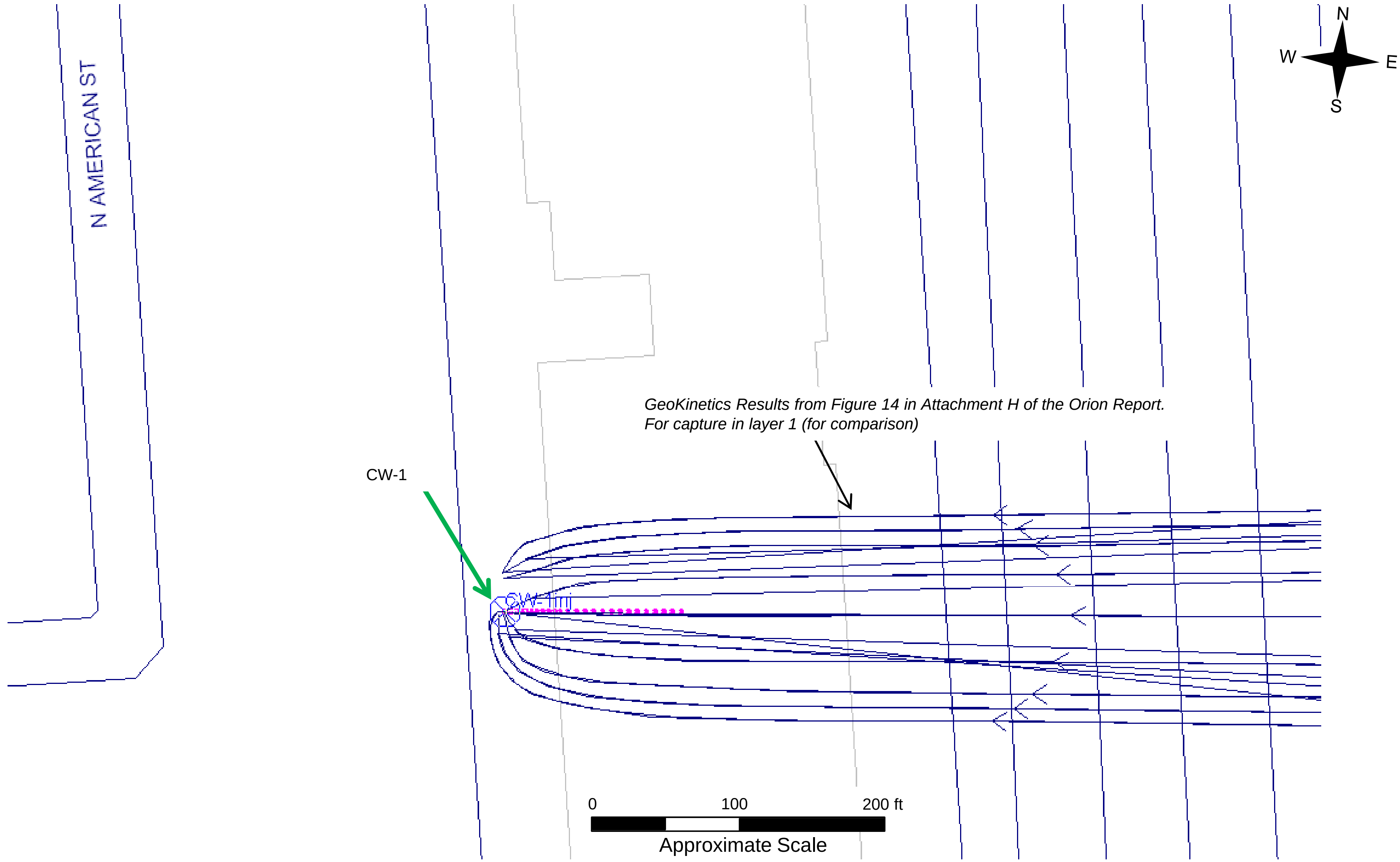
Figure 6



Blue = GeoKinetics Results from Figure 14 in Attachment H of the Orion Report

Magenta = GeoTrans Model Results, Capture for Particles Originating in Model Layer 3, Starting 50% up from the bottom of Layer 3 (capture zone continues to the east of the area illustrated)

Model Evaluation of Recirculation Well		
Recirculation Zone for Particles In Layer 3 Starting 50% from Bottom		
GeoTrans, Inc.	By: RMG Modified: 10/11/10	**Figure 7**



Blue = GeoKinetics Results from Figure 14 in Attachment H of the Orion Report

Magenta = GeoTrans Model Results, Capture for Particles Originating in Model Layer 3, Starting 5% up from the bottom of Layer 3 (capture zone continues to the east of the area illustrated)

Model Evaluation of Recirculation Well

Recirculation Zone for Particles In Layer 3 Starting 5% from Bottom

GeoTrans, Inc.

By: RMG

Modified: 10/11/10

Figure 8

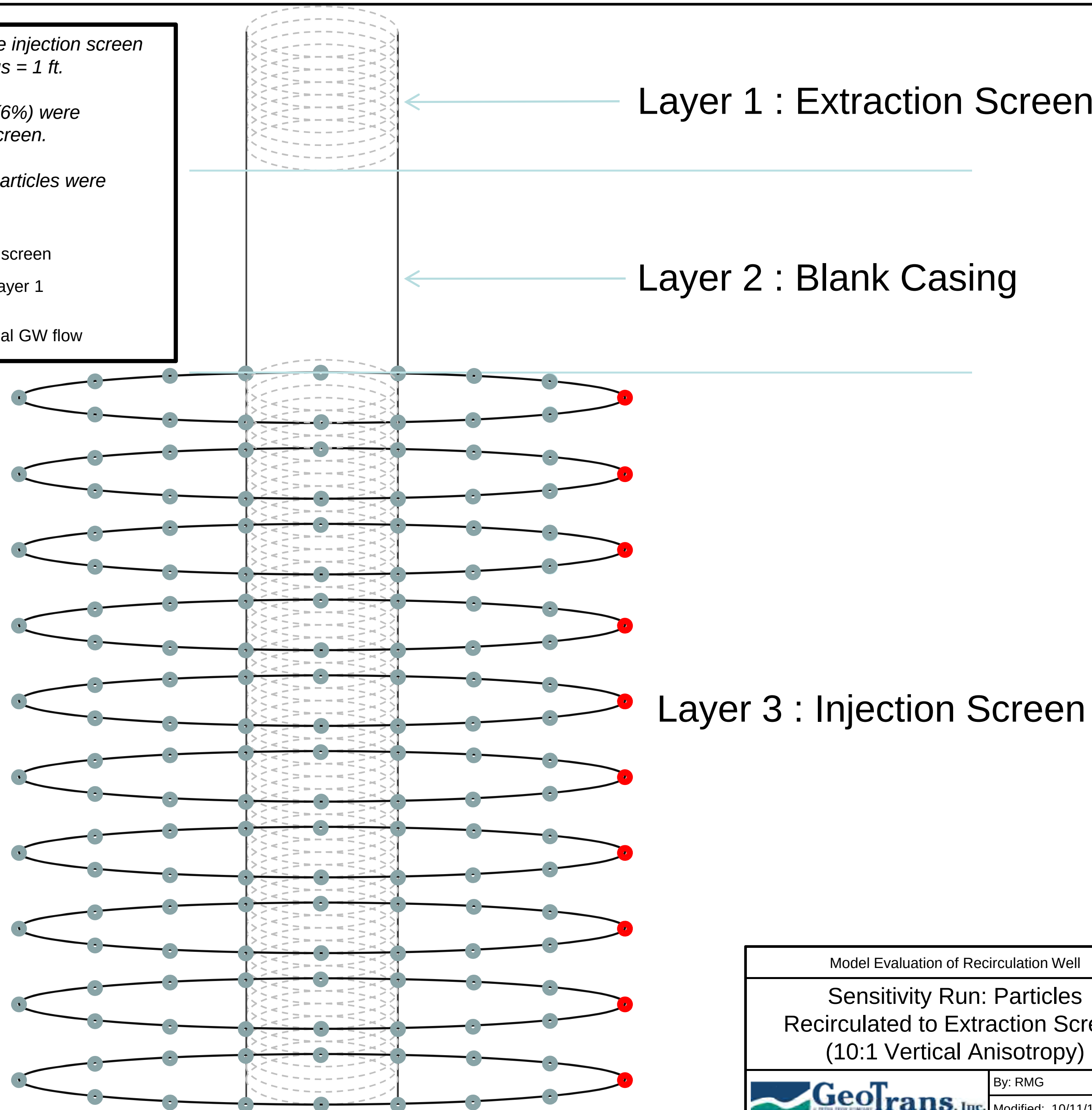
16 particles were started around the injection screen at 10 different depth intervals, radius = 1 ft.

Of those 160 particles, 10 of them (6%) were recirculated to the extraction well screen.

This figure illustrates which of the particles were recirculated.

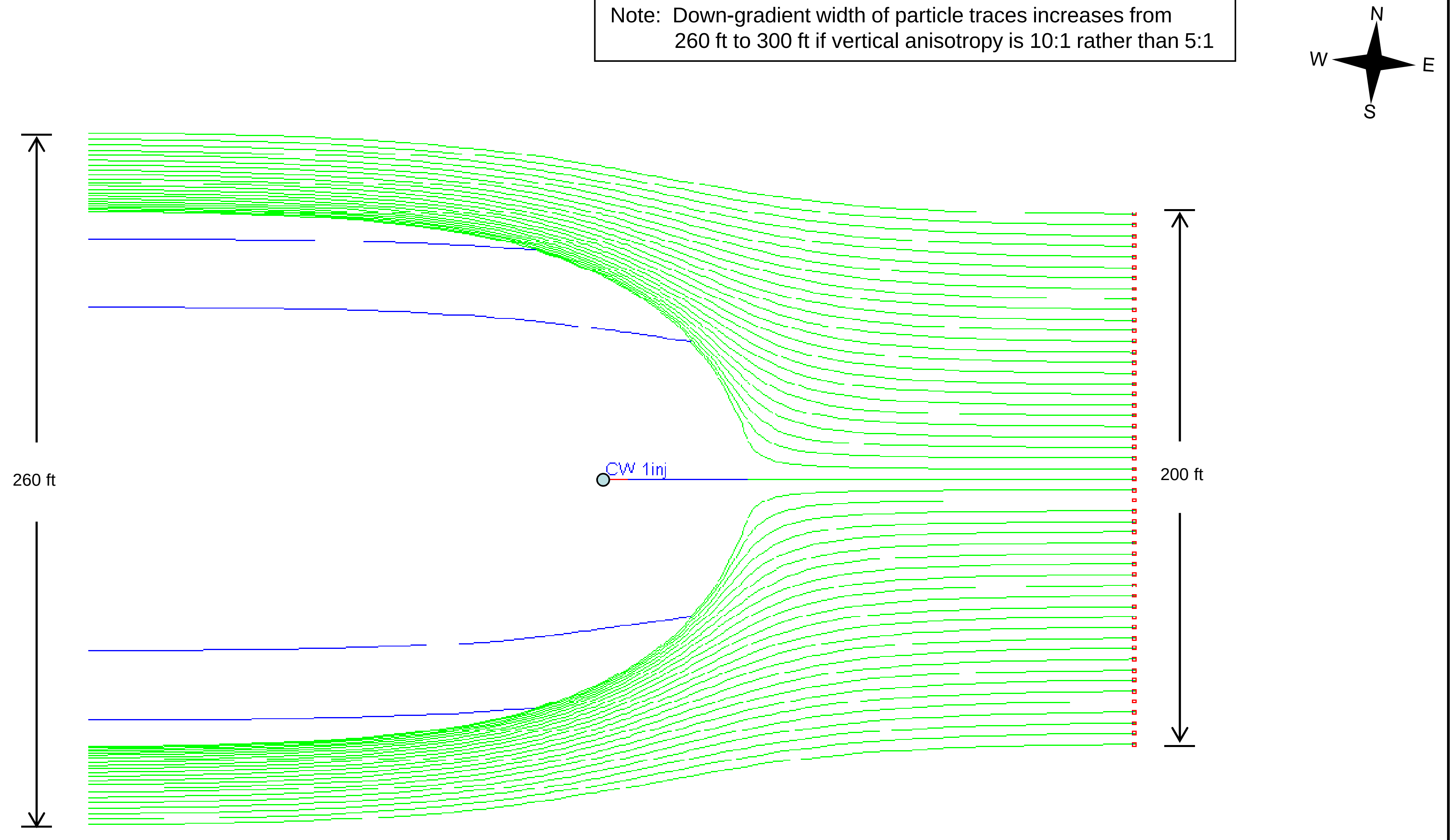
- Recirculates to layer 1 extraction screen
- Does not get extracted in model layer 1

← Direction of regional GW flow



Model Evaluation of Recirculation Well		
Sensitivity Run: Particles Recirculated to Extraction Screen (10:1 Vertical Anisotropy)		
GeoTrans, Inc.	By: RMG Modified: 10/11/10	Figure 9

Note: Down-gradient width of particle traces increases from 260 ft to 300 ft if vertical anisotropy is 10:1 rather than 5:1



Particle Trace Colors

Green = Model Layer 3

Blue = Model Layer 2

Red = Model Layer 1

0 100 200 ft

Approximate Scale

Model Evaluation of Recirculation Well

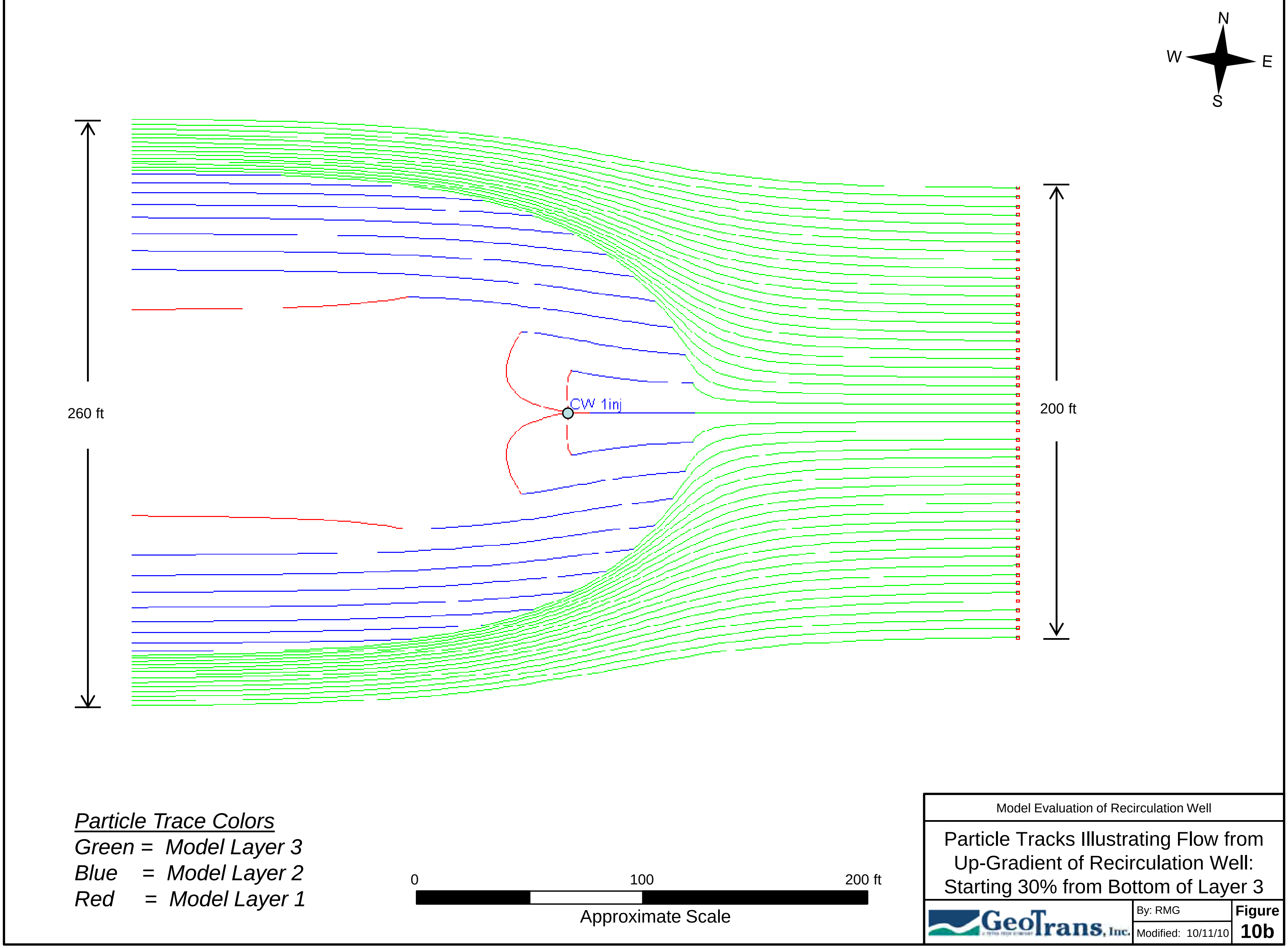
Particle Tracks Illustrating Flow from Up-Gradient of Recirculation Well: Starting 10% from Bottom of Layer 3

GeoTrans, Inc.

By: RMG

Modified: 10/11/10

Figure 10a



Model Evaluation of Recirculation Well

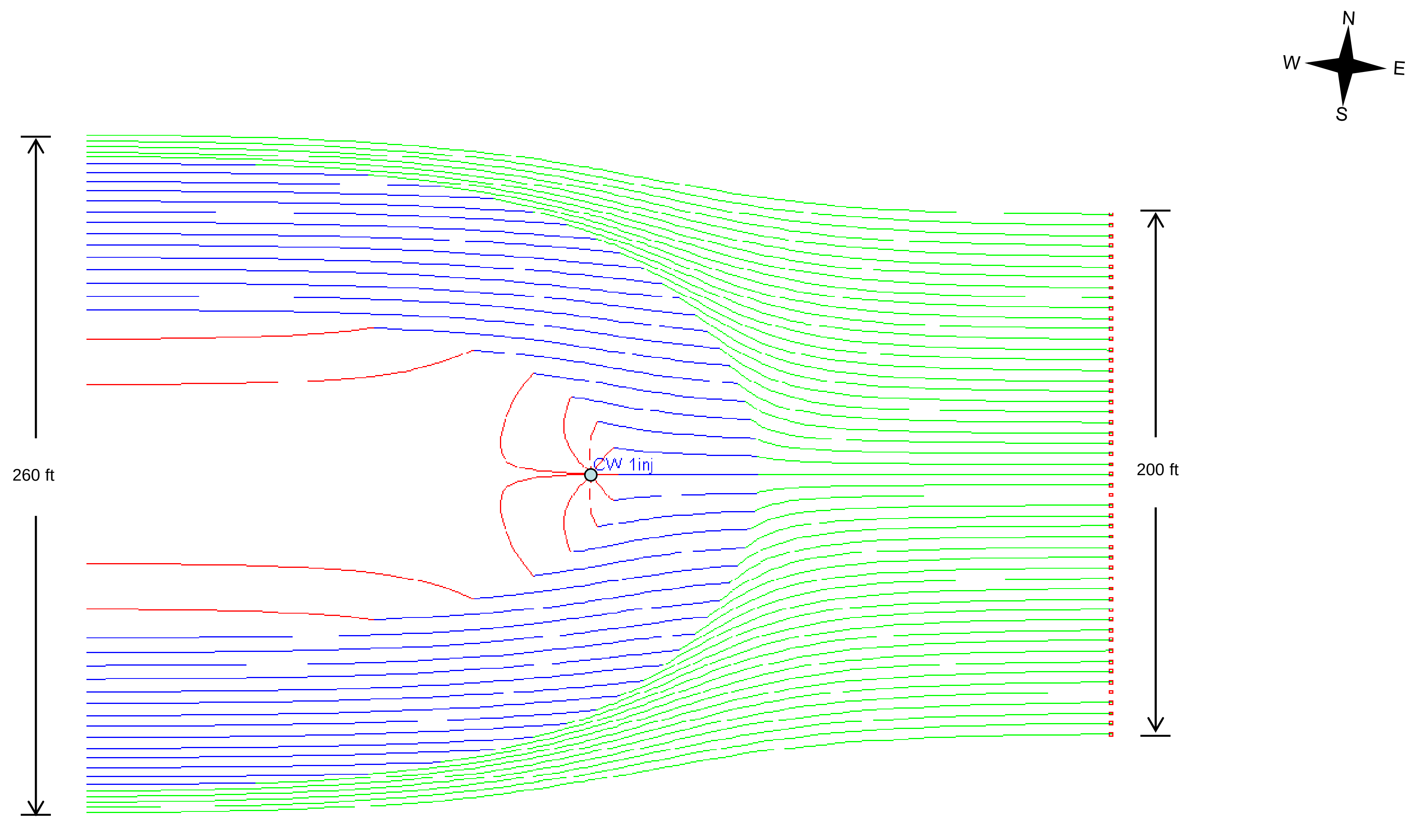
Particle Tracks Illustrating Flow from Up-Gradient of Recirculation Well: Starting 30% from Bottom of Layer 3

GeoTrans, Inc.

By: RMG

Modified: 10/11/10

Figure 10b



Particle Trace Colors

Green = Model Layer 3

Blue = Model Layer 2

Red = Model Layer 1

0 100 200 ft

Approximate Scale

Model Evaluation of Recirculation Well

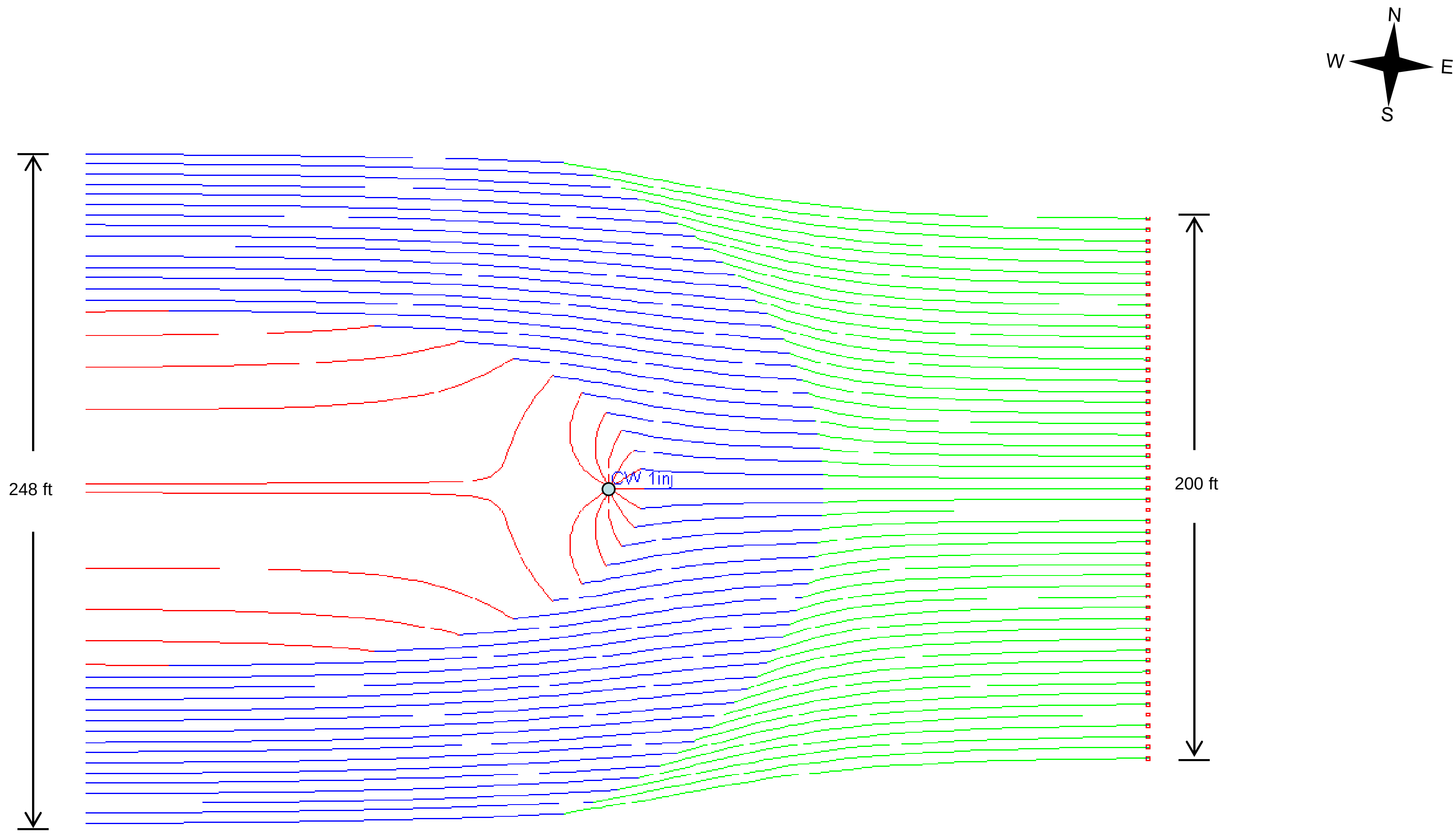
Particle Tracks Illustrating Flow from Up-Gradient of Recirculation Well: Starting 50% from Bottom of Layer 3

GeoTrans, Inc.

By: RMG

Modified: 10/11/10

Figure 10c



<u>Particle Trace Colors</u>

Green = Model Layer 3
Blue = Model Layer 2
Red = Model Layer 1

0 100 200 ft
Approximate Scale

Model Evaluation of Recirculation Well

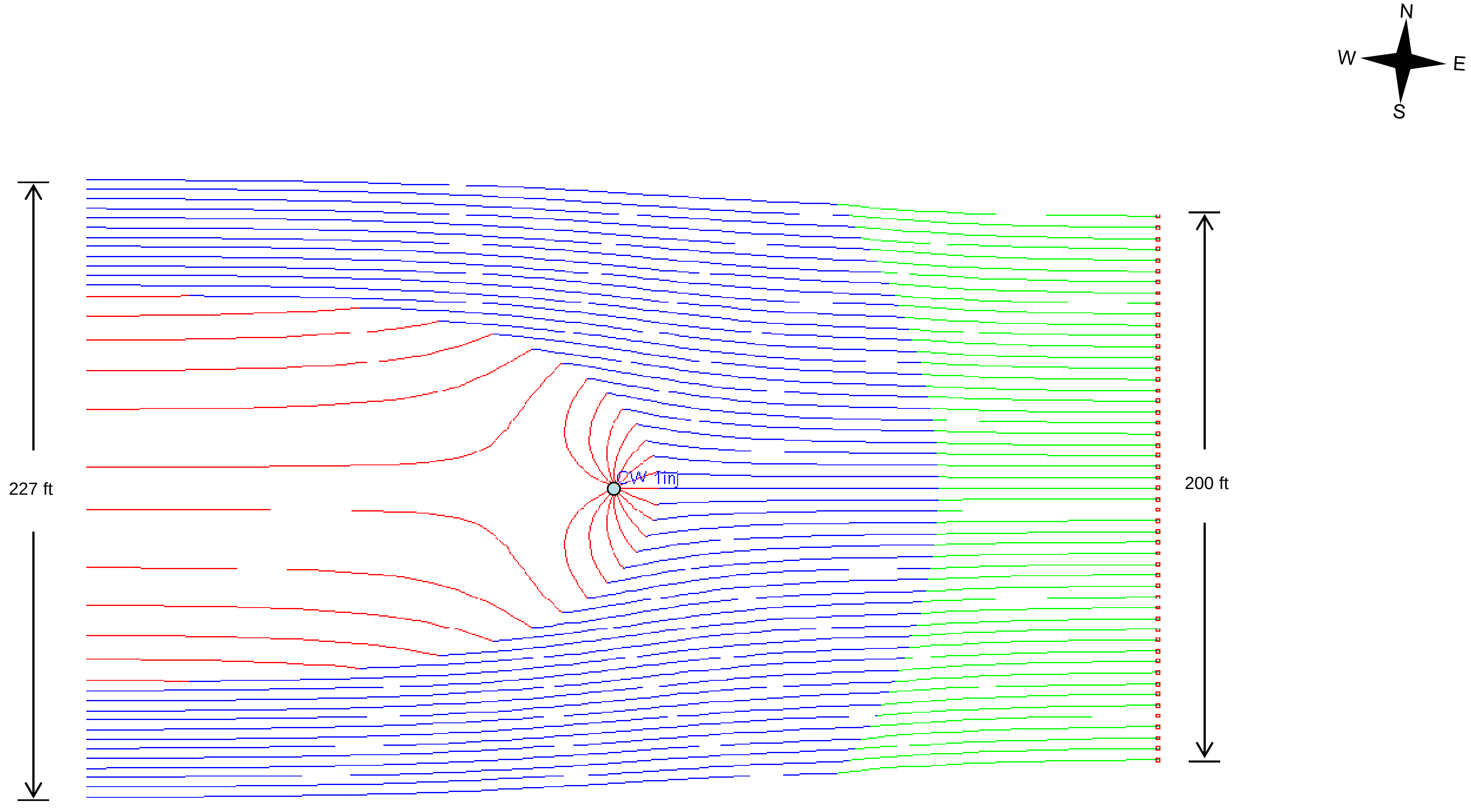
Particle Tracks Illustrating Flow from Up-Gradient of Recirculation Well: Starting 70% from Bottom of Layer 3

GeoTrans, Inc.

By: RMG

Modified: 10/11/10

Figure 10d



Particle Trace Colors
Green = Model Layer 3
Blue = Model Layer 2
Red = Model Layer 1

0 100 200 ft
Approximate Scale

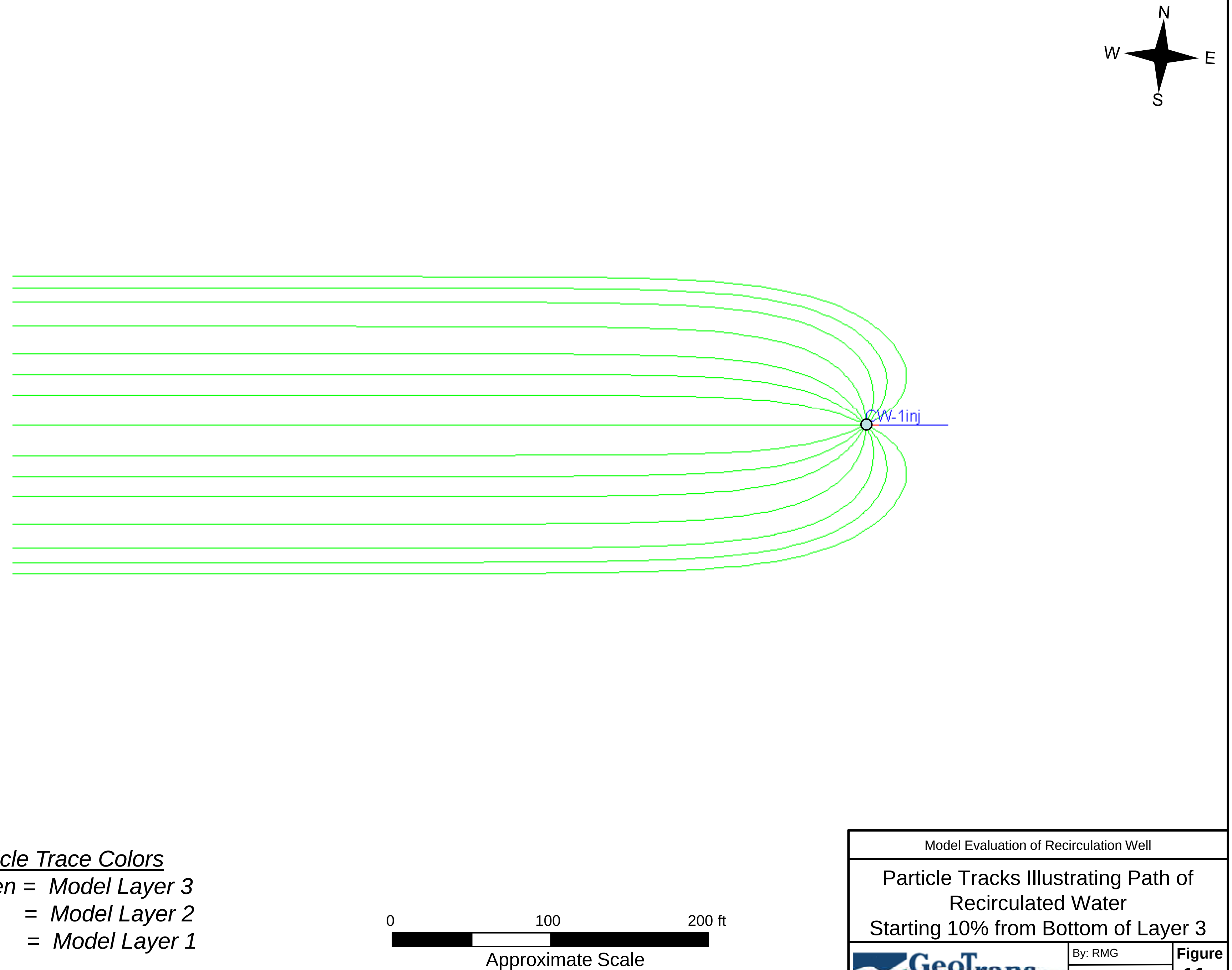
Model Evaluation of Recirculation Well

Particle Tracks Illustrating Flow from Up-Gradient of Recirculation Well: Starting 90% from Bottom of Layer 3

GeoTrans, Inc.

By: RMG
Modified: 10/11/10

Figure 10e



Particle Trace Colors
Green = Model Layer 3
Blue = Model Layer 2
Red = Model Layer 1

Model Evaluation of Recirculation Well

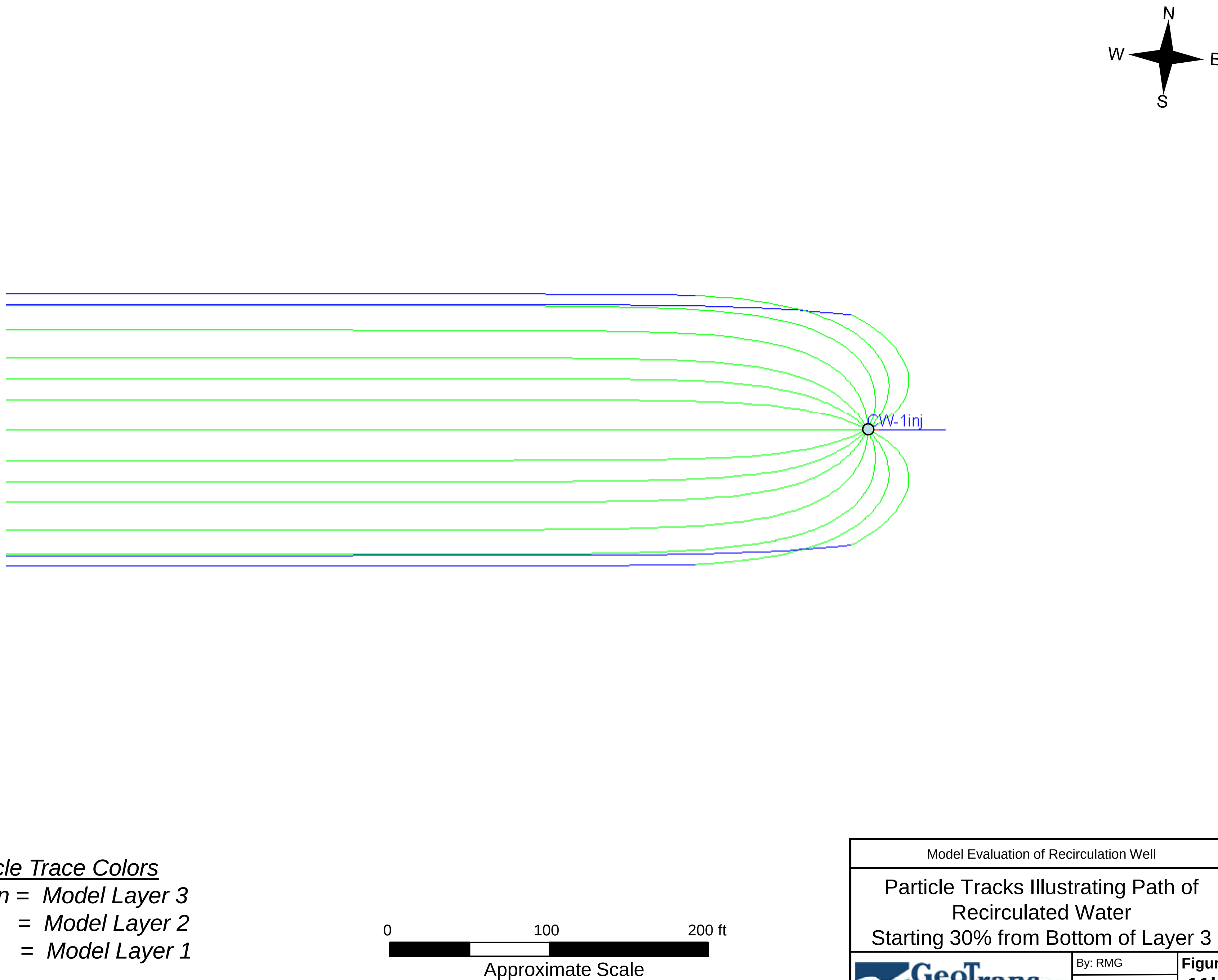
Particle Tracks Illustrating Path of Recirculated Water Starting 10% from Bottom of Layer 3

GeoTrans, Inc.

By: RMG

Modified: 10/11/10

Figure 11a



Particle Trace Colors
Green = Model Layer 3
Blue = Model Layer 2
Red = Model Layer 1

Model Evaluation of Recirculation Well

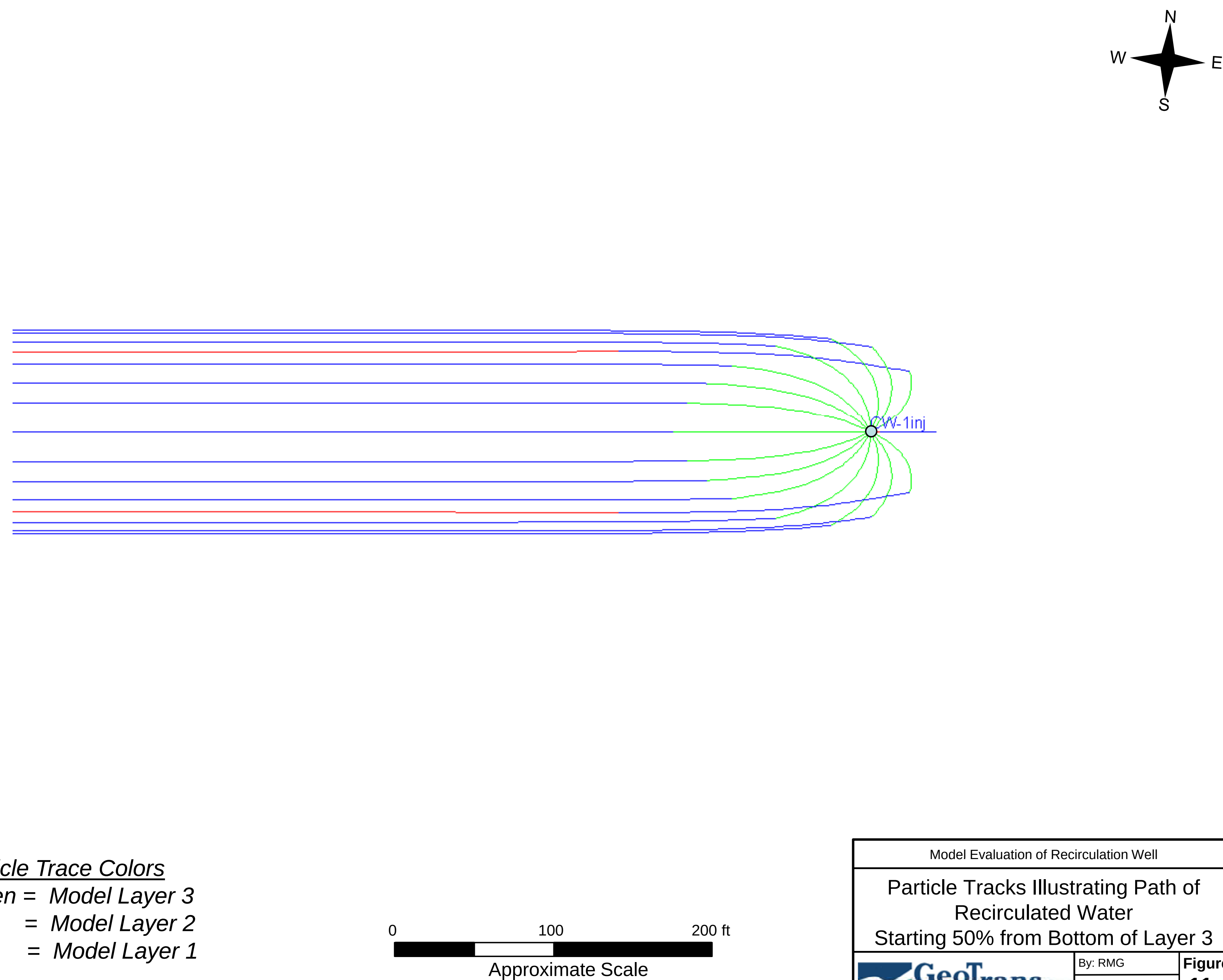
Particle Tracks Illustrating Path of Recirculated Water Starting 30% from Bottom of Layer 3

GeoTrans, Inc.

By: RMG

Modified: 10/11/10

Figure 11b



Particle Trace Colors

Green = Model Layer 3

Blue = Model Layer 2

Red = Model Layer 1

Model Evaluation of Recirculation Well

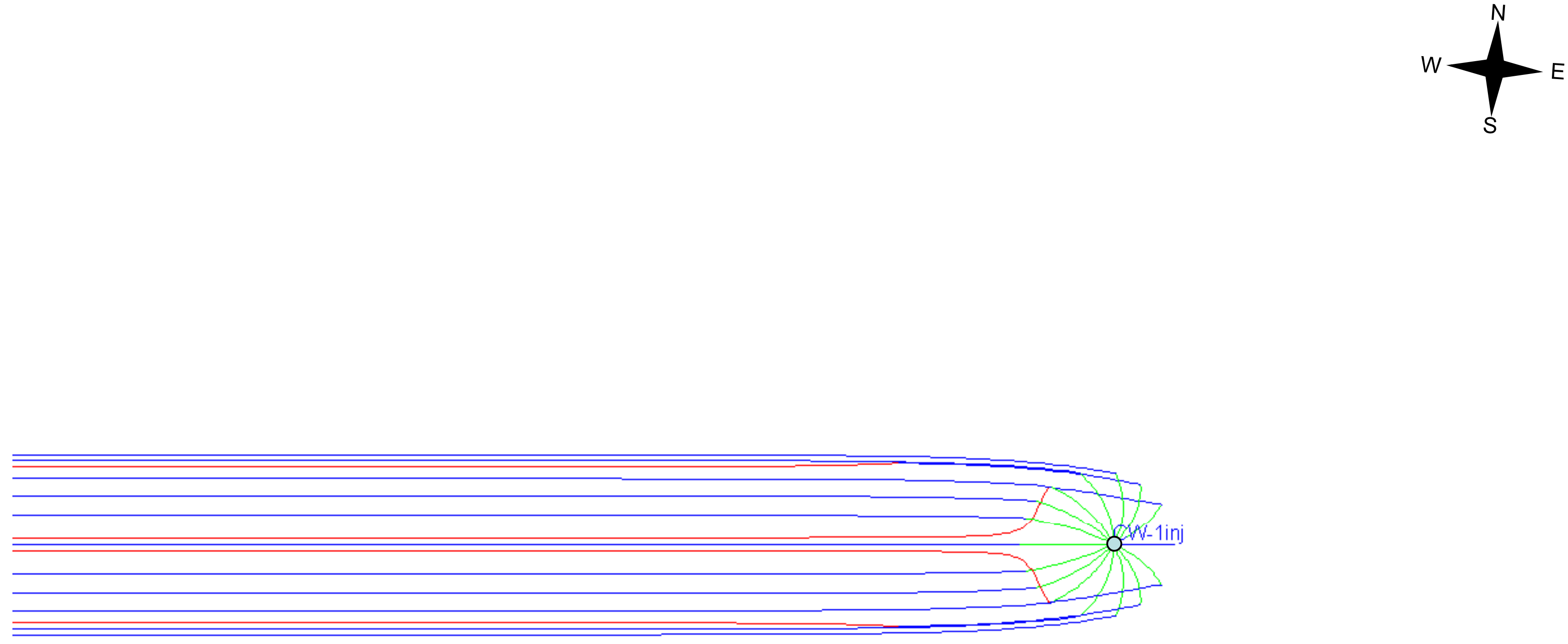
Particle Tracks Illustrating Path of Recirculated Water Starting 50% from Bottom of Layer 3

GeoTrans, Inc.

By: RMG

Modified: 10/11/10

Figure 11c



Particle Trace Colors
Green = Model Layer 3
Blue = Model Layer 2
Red = Model Layer 1

0 100 200 ft
Approximate Scale

Model Evaluation of Recirculation Well

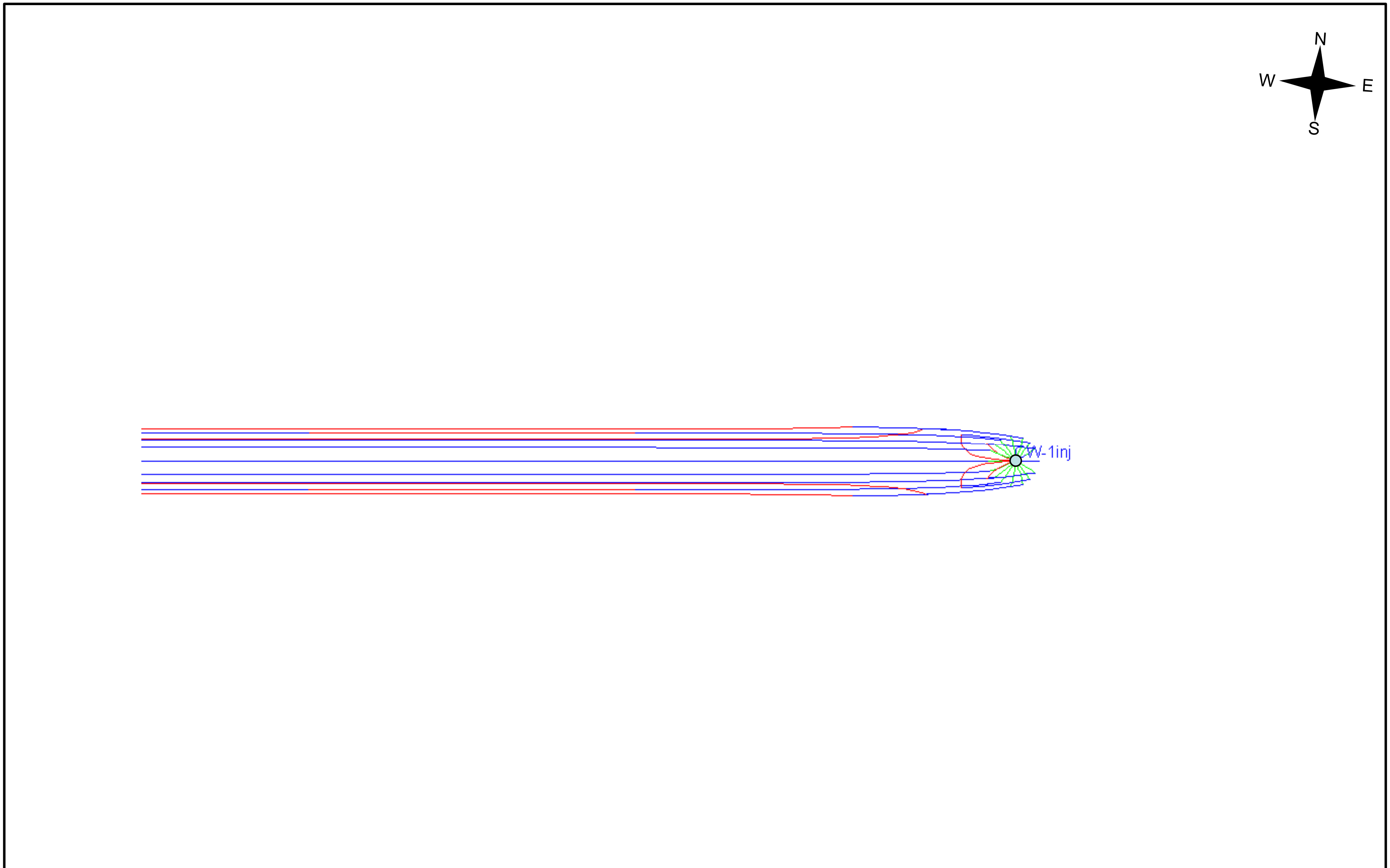
Particle Tracks Illustrating Path of Recirculated Water Starting 70% from Bottom of Layer 3

GeoTrans, Inc.

By: RMG

Modified: 10/11/10

Figure 11d



Particle Trace Colors

Green = Model Layer 3

Blue = Model Layer 2

Red = Model Layer 1

0 100 200 ft

Approximate Scale

Model Evaluation of Recirculation Well

Particle Tracks Illustrating Path of Recirculated Water Starting 90% from Bottom of Layer 3

GeoTrans, Inc.

By: RMG

Modified: 10/11/10

Figure 11e

Attachment A:

Selected Pages from “Attachment H” of Orion Environmental Report (4/23/10)

ATTACHMENT H

RADIUS OF INFLUENCE EVALUATION
PREPARED BY GEOKINETICS

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Introduction: A pilot test of a groundwater circulation well installed at the former Northrop Grumman Y-12 site has been performed to evaluate the effectiveness of this approach in remediating groundwater impacted with VOCs. The remedial approach involves the extraction of VOC-impacted groundwater from the upper portion of the Shallow Aquifer, the treatment of that water using an advanced oxidation process, and the recharge of the treated water to the lower portion of the Upper Shallow Aquifer. Each of these processes (extraction / treatment / recharge) takes place within the pilot test well. A schematic illustrating the configuration of the pilot test well is provided as Figure 1. A drawing illustrating the configuration of the test well circulation pump, the advanced oxidation reaction vessel, and the sampling pumps is provided as Figure 2. A photograph of the pump assembly is provided as Figure 3. Two separate pumps with variable speed controllers were used at different times during the pilot testing activities to evaluate the circulation well under a wide range of pumping rates. These included a larger, 7½ horsepower pump that was operated at flow rates up to 200 gpm and a smaller, 5 horsepower pump that was operated at flow rates up to 140 gpm. The flow rates of both pumps were calibrated with the variable speed controller in the laboratory prior to field use. The results of this calibration are presented in Figures 4 and 5. The response of the pilot test well (i.e. draw down in upper screen and over-pressure in lower screen) was measured at various flow rates throughout the testing program. The hydraulic response of the test well is illustrated in Figure 6.

The effective radius of influence of the circulation well was evaluated during the pilot test using three separate methodologies. These included:

1. Monitoring and evaluation of the induced piezometric levels in multistage standpipes installed in the vicinity of the circulation well;

2. Monitoring and evaluation of the groundwater chemistry and contaminant levels in multistage standpipes installed in the vicinity of the circulation well; and

3. Groundwater modeling to simulate the circulation well operation under various operating scenarios.

The results of each of these assessments are discussed separately below.

Piezometric Levels: The locations of the circulation well (CW-1) and nearby monitoring wells are shown in Figure 7. Monitoring of the groundwater elevations at the site prior to the initiation of the pilot test generally indicated a slight downward flow gradient within the Shallow Aquifer. This is consistent with data reported for other monitoring wells screened within the Shallow Aquifer at the site and in the site vicinity. The static piezometric levels measured in the circulation well and nearby standpipes screened within the Shallow Aquifer prior to initiation of the pilot test in October of 2009 are summarized below:

Well	Piezometric Level (Feet)		
	Upper Screen	Lower Screen	Difference
CW-1	48.07	47.36	+0.71
MW-15	46.89	46.77	+0.12
MW-16	47.29	47.31	-0.02
MW-17	47.33	47.24	+0.09
		Average:	+0.23

As indicated, the static piezometric levels in the upper portion of the Shallow Aquifer were, on average, 0.23-feet higher than those in the lower portion of the aquifer.

A clear reversal of the downward gradient was consistently induced in monitoring well MW-17 (25 feet away from CW-1) within approximately 30 minutes of initiating operation of the circulation well. During the most recent phase of the pilot test with the pump operated at 60 gpm, the piezometric head in the lower screen of MW-17 has been maintained approximately 0.25 feet above that in the upper screen. A graph depicting the water elevations in the shallow and deep screens of MW-17 is provided as Figure 8. A well defined and persistent reversal of the normal downward flow gradient has not occurred in MW-16 (75 feet away) or MW-15 (150 feet away) at the 60 gpm flow rate - although some impact on the piezometric levels in these standpipes appears to have occurred. Graphs depicting the water elevations in the shallow and deep screens of MW-16 and MW-15 are provided as Figures 9 and 10, respectively.

Water Quality: Changes in the chemistry or contaminant levels of the groundwater within the deeper screens of the monitoring wells provides the most direct and clearest indication of the zone of influence of the circulation well. The groundwater PCE concentrations measured within the upper, intermediate, and lower screen intervals of monitoring wells MW-17, MW-16, and MW-15 are illustrated in Figures 11 thru 13, respectively. As shown, the groundwater PCE levels in each of the deep casings exhibited significant reductions in response to the pilot testing activities. These reductions are summarized below:

Well	Distance From CW-1	Deep Casing PCE Level (μg/L)		
		Start of Pilot Test (10-20-09)	Most Recent (3-1-10)	Reduction
MW-15	150 ft	34.0	1.6	95%
MW-16	75 ft	32.8	8.0	75%
MW-17	25 ft	29.2	0.8	97%
			Average:	89%

As shown in Figures 12 and 13, a slight rebound in the PCE levels appears to have occurred in the deep casings of MW-15 and MW-16 in early to mid-January of 2010. This rebound appears to be associated with the 29 day period between the termination of Pilot Test #1 on November 19^{th} and the initiation of Pilot Test #2 on December 17^{th}, 2009. It is significant to note that pumping of the circulation well at 60 gpm was sufficient to eliminate the rebound - even in MW-15 located 150 feet away from the circulation well.

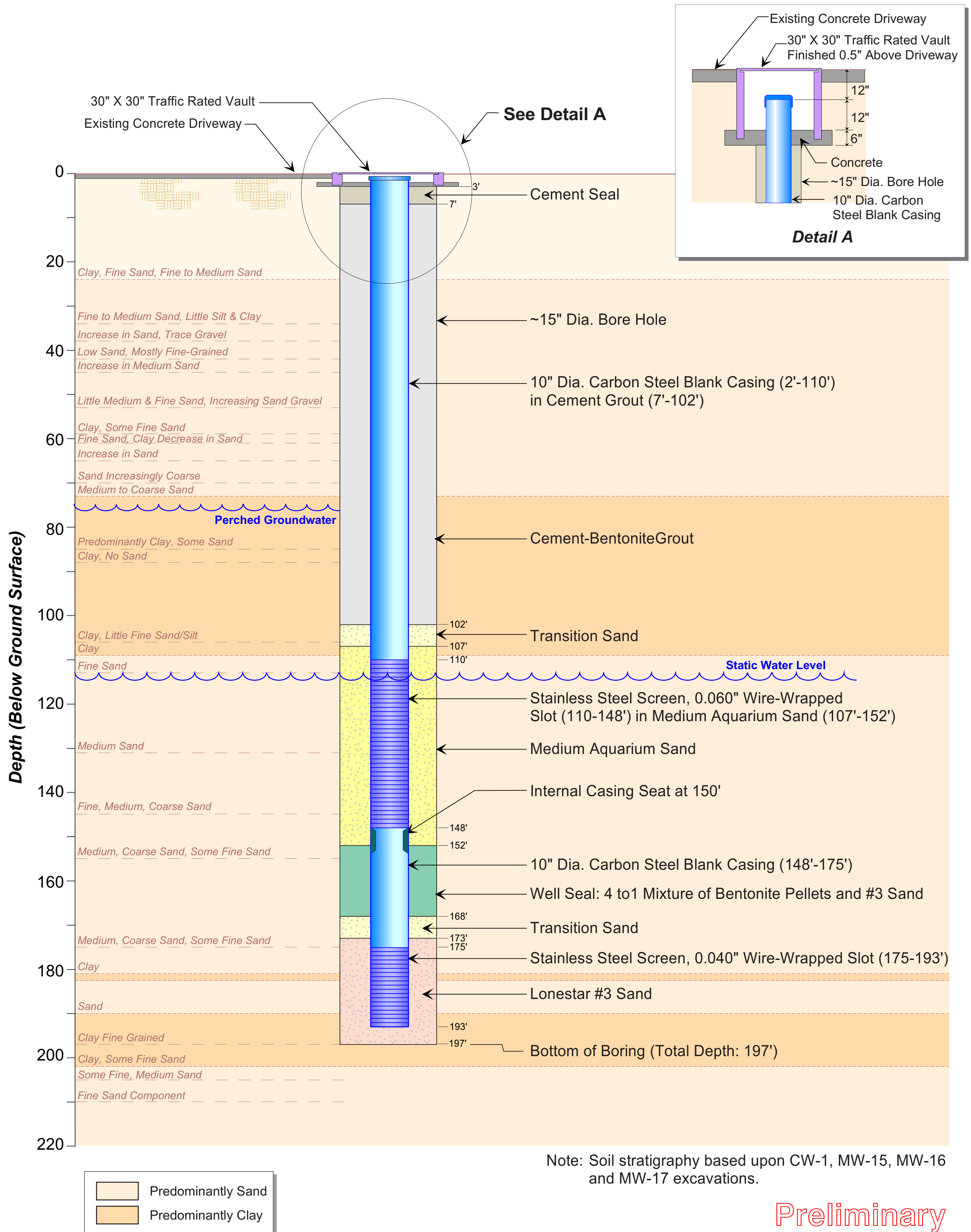
Groundwater Modeling: Numerical modeling was performed to evaluate the hydraulic flow characteristics of the circulation well and to assess its effectiveness at different pumping rates. A large-scale three-dimensional groundwater model developed for the Orange County groundwater basin by the Orange County Water District (OCWD) was used as a basis for a more refined model of the Y-12 area. The model is based upon the well established USGS MODFLOW code for groundwater flow. The USGS MODPATH code was utilized for particle tracking and capture zone analysis. Key input parameters for the model, such as hydraulic conductivity, effective porosity, aquifer thickness, etc. were initially based on the basin-wide groundwater model developed by OCWD and available data regarding the lithology of aquifer in the vicinity of the Y-12 site. These parameters were refined based upon the measurements that were made during the pilot test. The following model parameters provided the best fit between predicted and measured piezometric levels:

Parameter	Value
Horizontal Hydraulic Conductivity (K_H)	450 ft/day
Vertical Hydraulic Conductivity (K_V)	90 ft/day
$K_H : K_V$	5:1
Effective Porosity	25%

These values are consistent with those utilized in the OCWD model within the Anaheim Forebay area.

To simulate the pilot circulation well, Telescopic Mesh Refinement (TMR) was used to create a more localized, higher resolution mesh within the larger basin model at the Y-12 location. TMR facilitated the creation of a model with finer grid spacing while maintaining the layering, aquifer parameters and overall flow conditions that are present in the larger model. The finer grid spacing of the refined model allows better resolution of groundwater flow rates and patterns to assist in estimating the recirculation well capture zones. The Shallow Aquifer is represented by model layer 1 in the Anaheim Forebay model. In the refined model, the saturated zone of the Shallow Aquifer was subdivided into three layers of equal thickness and identical aquifer parameters. To simulate a recirculation well, the model specified pumping from the upper portion of the Shallow Aquifer (layer #1) and recharge to the lower portion of the Shallow Aquifer (layer #3), with no pumping or recharge simulated in the intervening layer (layer #2). The pumping/injection rates were varied during different model simulations and particle tracking was used to evaluate groundwater flow patterns and to assess the zones of influence for the upper and lower screened intervals. The predicted groundwater flow pattern for a 60 gpm pumping rate is illustrated by the particle tracking arrows in Figure 14. The predicted drawdown within the upper portion of the Shallow Aquifer and the predicted over-pressure within the lower portion of the Shallow Aquifer induced at various rates of pumping are illustrated in Figure 15. The associated width of the capture zone that is predicted by the groundwater model is illustrated in Figure 16 as a function of the rate of pumping. As shown, an effective contaminant capture zone on the order of 300 feet (150 foot radius) appears to be achievable based on the available data.

Conclusion: At the current 60 gpm circulation rate, the pilot circulation well is estimated to have an effective capture radius of approximately 60 feet within the upper portion of the Shallow Aquifer and an effective radius of recharge influence in excess of 150 feet within the lower portion of the Shallow Aquifer. The data collected from the pilot testing activities indicates an effective contaminate capture radius of approximately 150 feet is achievable within the upper portion of the aquifer at higher pumping rates. Enhancements to the exterior seal of CW-1 would be necessary in order top operate the well for an extended period of time at higher pump rates. Without these enhancements, the CW-1 pumping rate should be maintained at or below approximately 100 gpm. The pilot test results indicate the operation of a circulation well represents an effective, and relatively economical, means of intercepting and destroying VOCs that would otherwise migrate downgradient of the Site.



Note: Soil stratigraphy based upon CW-1, MW-15, MW-16 and MW-17 excavations.

Preliminary
For Mediation Purposes Only

Not to Scale

March 2010

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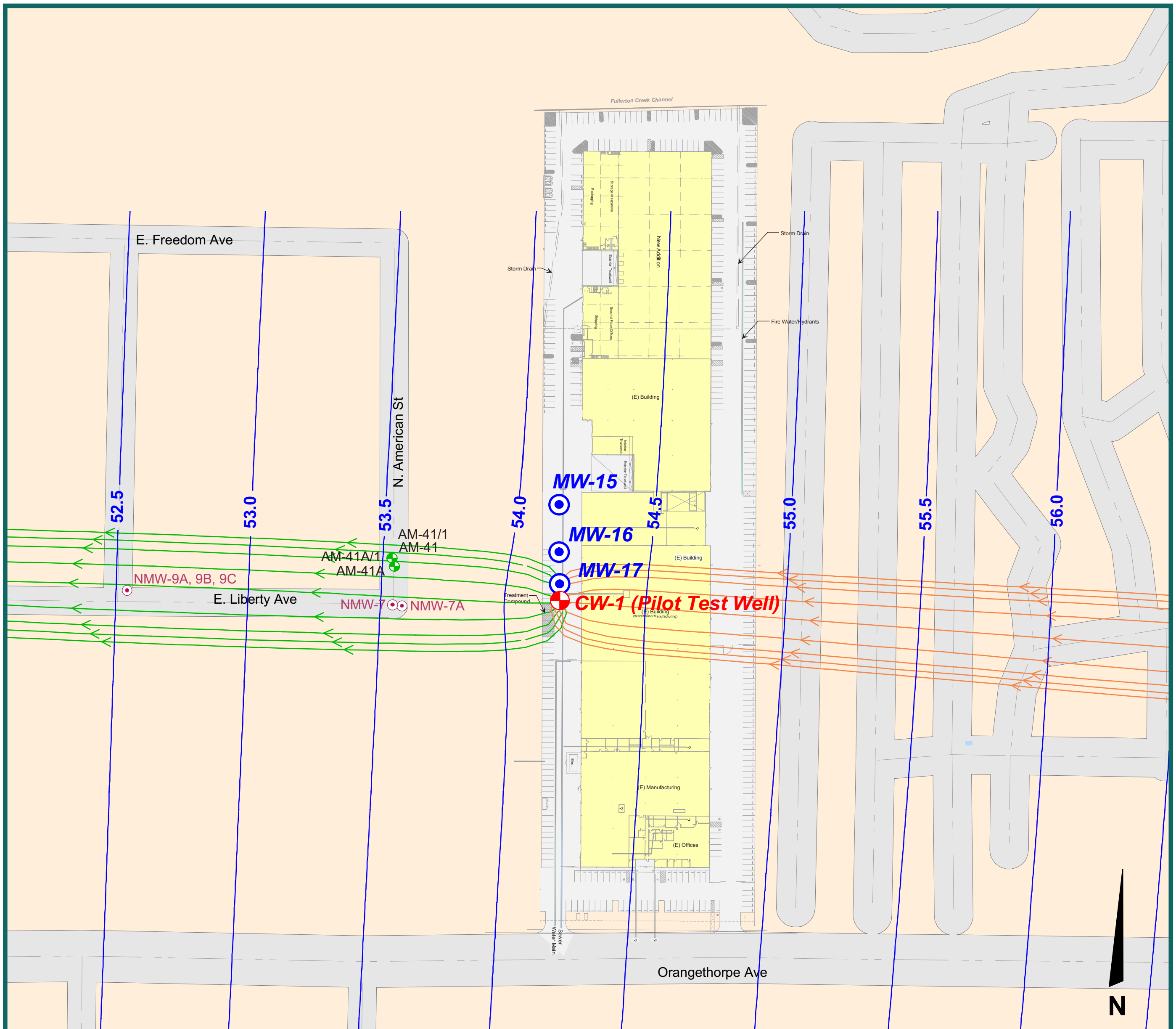
Schematic of Pilot Test Well CW-1

Figure 1



Legend

CW-1	Location of Circulation Well
MW-17	Location of Supplemental Multi-Stage Monitoring Well
52.5	Modeled Groundwater Elevation Contour
	Modeled Extraction Pattern from Upper Zone Arrow Length Denotes Particle Travel Over 30 Days.
	Modeled Dishcharge Pattern to Lower Zone - Arrow Length Denotes Particle Travel Over 30 Days.
NMW-5	Northrop Groundwater Monitoring Well
AM-41/1	Other Groundwater Monitoring Well

Conditions

- *60 gpm Circulation Rate*
- *Extract from Upper Zone of Shallow Aquifer / Discharge to Lower Zone of Shallow Aquifer*
- *Particle Tracking Arrow Lenth = 30 Day Travel Time*

0 250 500 Feet

Approximate Scale

Preliminary

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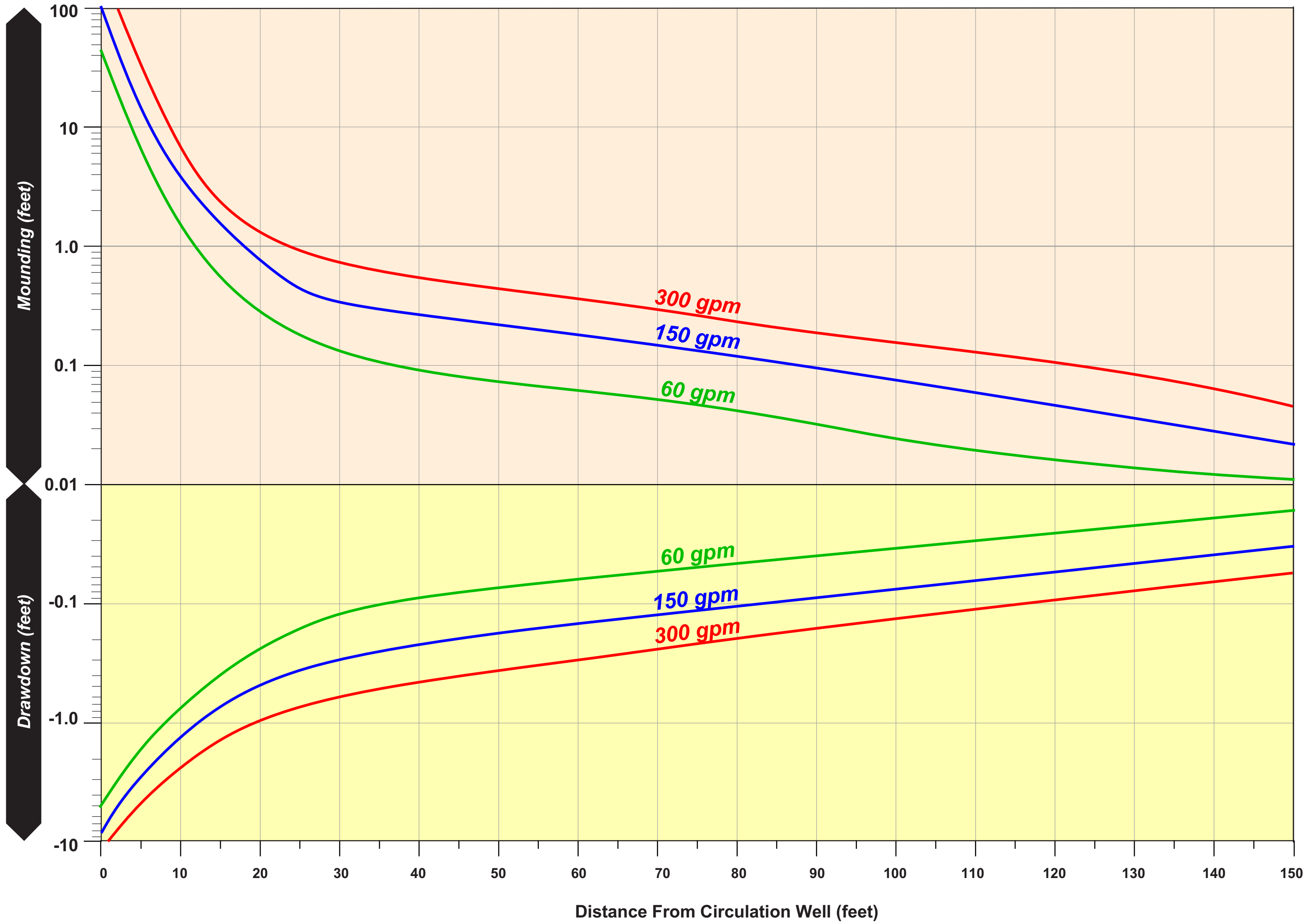
Y-12 Site Plan with Configuration of Groundwater Circulation Well

Figure 14



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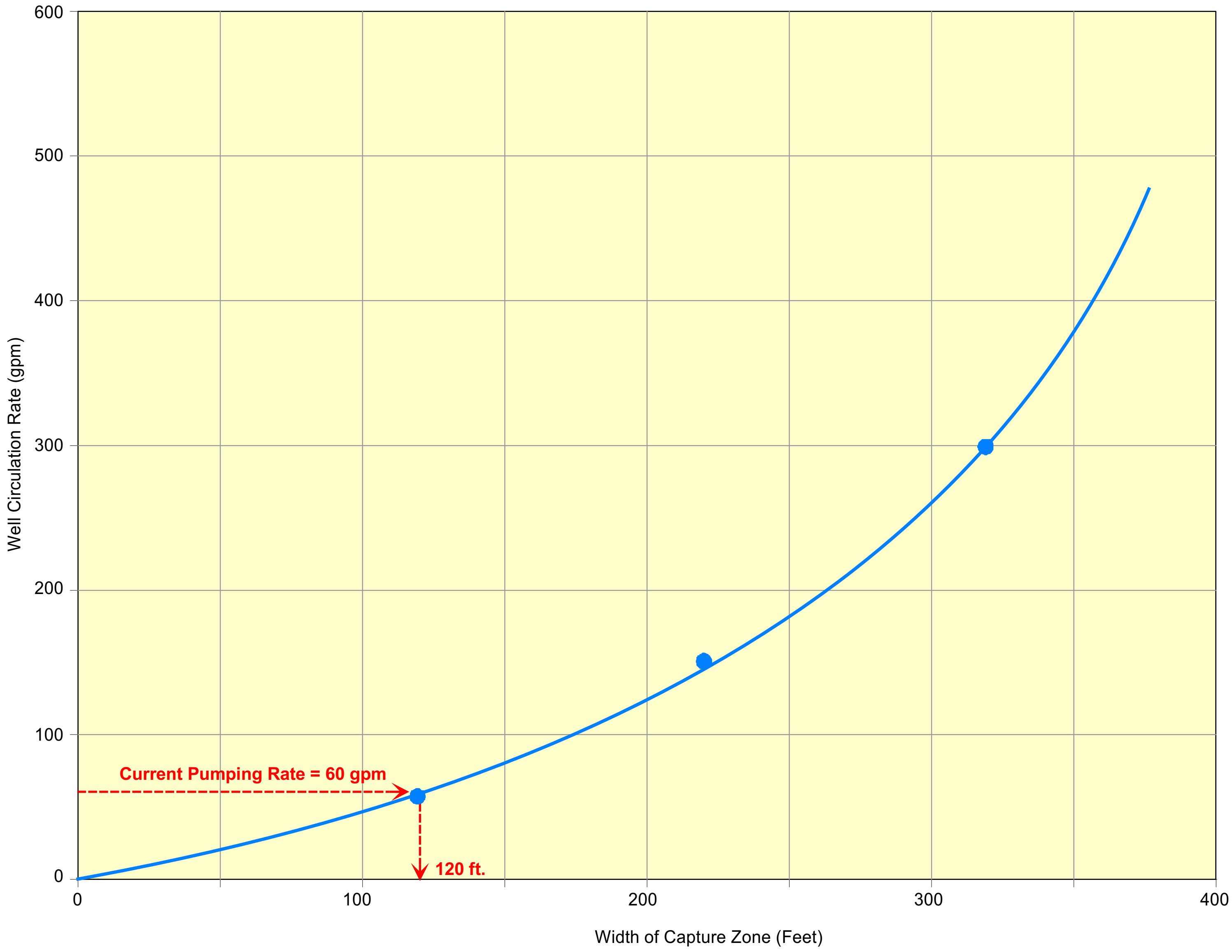
Groundwater Capture Zone Modeling Results

Figure 15



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Relationship Between Well Circulation Rate and Capture Zone for Upper Shallow Aquifer in Area of Y-12 Facility

Figure 16